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THE ASSOCIATION was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of over **700** men. Its membership is divided into two principal classes, viz.: MEMBERS and ASSOCIATES. Members are divided into two classes, viz.: RESIDENT and NON-RESIDENT, — the former comprising those residing within the limits of New England, while the latter class includes those residing elsewhere. The INITIATION fee for the former class is FIVE dollars; for the latter, THREE dollars. The annual dues for both classes of Active membership are THREE dollars. Associate membership is open to firms or agents of firms engaged in dealing in water works supplies. The initiation fee for Associate membership is TEN dollars, and the annual dues FIFTEEN dollars. This Association has six regular meetings each year, all of which, except the annual convention in September, are held at Boston.

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New England Water Works Association.

ORGANIZED 1882.

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This Association, as a body, is not responsible for the statements or opinions of any of its members.

HOW THE WATER EMERGENCY AT WORCESTER, MASS., WAS HANDLED IN THE SUMMER OF 1911, TOGETHER WITH A BRIEF DESCRIPTION OF WORCESTER'S SOURCES OF WATER SUPPLY.

BY FRANK C. KIMBALL.

[*Read March 13, 1912.*]

In the summer of 1911 the city of Worcester, Mass., experienced a water shortage, not to call it a famine. Several possible sources of supply to relieve the stringency were considered, and, while some of them were later used to some extent, it was soon recognized that about the only source which combined both quantity and quality was the Wachusett reservoir of the Metropolitan Water Works, in the towns of Boylston and West Boylston. The nearest available point at which this source could be tapped was about eight miles from the City Hall in Worcester, and at an elevation at high water of about 92 ft. below the street at the City Hall, about 330 ft. below the low-service reservoir supply and about 435 ft. below the level of the high-service reservoirs of Worcester. It, therefore, was a serious question — at a time when the water stringency had become so great that further delay could not be tolerated, — whether the necessary pipes, machinery, etc., could be obtained and installed in season to be of benefit to the city. In fact, at a conference between the State Board of Health and officials of the city of Worcester in Boston, on July 20, the opinion

was expressed by the chairman of that board, that it would be a physical impossibility to get the Metropolitan water into the city in time to be of use.

It was fortunate for the city that it had as its mayor at this time, the Hon. James Logan, a thoroughly trained business man, versed in handling large business enterprises and, therefore, capable of dealing with the important questions involved in an undertaking of this character. Believing that the materials could be found and the work done, all without unnecessary delay if the problem were attacked in the right way, he lost no time in getting in touch with various parties whom he thought might help the city in its crisis. Among others whom he consulted in the matter was the Stone & Webster Engineering Corporation of Boston, who, while not to any material extent operating along water-works lines, suggested certain ways and methods by which it was thought the project could be carried out. Examinations were made by them in behalf of the city, together with some inquiries as to the possibility of obtaining the necessary supplies to prosecute the work.

On Friday noon of August 4, the writer was asked by Mr. F. N. Bushnell, engineering manager of that corporation, to go to Worcester, examine certain proposed routes for a pipe line from Wachusett reservoir to the city, determine the sizes of pipe necessary to deliver over the routes examined not less than 6 000 000 gal. of water daily into its low-service system, and to report in full by the following Tuesday at noon. He spent that afternoon and the following day going over the ground as well as following up the situation in the offices of the city engineer and of the water commissioner, including also several conferences with the mayor and the city attorney, and on Tuesday noon submitted his report to Mr. Bushnell, followed the next day with an estimate in detail of the cost of so much of the work as had been embraced in his studies. This report recommended the route finally adopted but with the further recommendation that certain reinforcing mains be laid by and in the city to supplement those already in place between that section known as "Summit,"— where it was proposed to connect with the city's mains, — and Lincoln Square, where it was required to deliver the water to a 30-in. low-service

pipe. Attention was also directed to the fact that even with these changes it might be difficult to give proper service to certain portions of the city on Burncoat Hill and in the Greendale section if the high-service mains then supplying these sections were diverted from their uses and used to bring in the water for the low-service supply.

Owing to the illness of the city engineer, Mr. Frederick A. McClure, Mayor Logan on Wednesday, August 9, appointed Mr. Charles A. Allen, M. Am. Soc. C. E., formerly city engineer of Worcester and member of long standing in this association, as consulting engineer upon the entire question of emergency supplies of water, he to assume control of all construction required by whatever plans were adopted, and particularly to see that the work was prosecuted to a speedy conclusion. Acting at once in the matter, on the following day he in company with the mayor had a conference at the office of Stone & Webster with members of that organization, at which the writer was present, where all information gathered by that concern was placed at the full disposal of the city and the tender of such assistance as they could render them, made. As one of the results of this conference, on the following Saturday, August 12, the writer was engaged by Mr. Allen to assist him in carrying out the work for which he had been retained, and he immediately went to Worcester for that purpose.

As there was at this time less than 80 000 000 gal. in the low-service reservoirs, and the almost certain necessity was seen of having to use the water in the high service to supplement the low before the Metropolitan supply could be completed, it was early decided by Mr. Allen that any supply brought to the city would have to be under a pressure sufficient to supply the high service as well as the low and of such capacity that, if weather conditions did not help the city, it would be ample for practically the entire daily consumption. Further, as, by so doing, the complications due to attempting to use certain of the high-service mains under low-service conditions would be obviated, the plans finally adopted were upon the basis of pumping 10 000 000 gal. a day into the high service.

It was further decided to take the water, subject to the per-

mission of the Metropolitan Water and Sewerage Board, from a point in Wachusett reservoir in South Bay, near the entrance of Muddy Brook, so called, and where at high water there was a depth of upwards of 40 ft., and to bring the supply into Worcester by way of Hartwell and Burncoat streets, delivering it to the city's high-service mains at West Boylston and Mountain streets in that section of the city known as "Summit." To reduce the friction head as much as possible, a 30-in. pipe line was found to be desirable. Estimates of cost covering the work upon this plan were made and submitted to the mayor on the morning of August 14, and by him transmitted to the City Council that same evening, at which time by resolution, the consulting engineer, Mr. Allen, under the direction of the mayor, was ordered to proceed with the work and do all things necessary to procure and make available at the earliest possible moment an emergency water supply delivered into the high-service mains as above outlined. The estimated cost of this work, $153 000, was, with other amounts, appropriated at this same meeting.

The necessity of changing the plan so as to permit of taking care of the high as well as of the low service, and of providing sufficient capacity to substantially meet the full daily needs of the city, as well as the need of haste in the execution of the work, may be seen from the fact that on August 5, with a daily average consumption in the month of July of about 10 700 000 gal., of which about 4 850 000 gal. came from the high-service sources, and about 5 850 000 gal. from the low service, there was in storage, in the Tatnuck or low-service reservoirs, only about 80 000 000 gal., and in the Kettle Brook and Lynde Brook reservoirs, supplying the high service, about 580 000 000 gal. Thus the low service had only about fourteen days' supply on that date for its portion of the city, after which, if not replenished, the high-service supplies would have to be called upon to supply the entire city. Upon the assumption, fair at this season of the year, — August and September, — that any yield from the watersheds would probably be sufficient only to care for evaporation at the best, the entire supply in storage on August 5, about 660 000 000 gal., after deducting such of it as was not available, would supply the city for from sixty to sixty-five days.

In order that a clear understanding of the situation at this time may be had, a brief description of the various sources supplying Worcester will be of interest.

At this time, all of its water supply is obtained by gravity from three brooks, all tributary to the Blackstone River. These had been developed by the construction of dams across these streams at advantageous points, thus forming seven storage reservoirs. The accompanying map (Plate II) has been prepared through the courtesy of the city engineer's office in Worcester, and outlines these various supplies, indicating as well certain contemplated additional sources from which Worcester expects to draw, as well as showing the various emergency sources utilized in the summer and fall of 1911.

The original source of Worcester's water supply was Bell Pond on Belmont Hill, which in turn was fed by an aqueduct from Putnam's Meadow, so called, to the northeast of this pond. This was the sole supply of the city until the early '70's when the Lynde Brook supply was developed. After Lynde Brook supply was turned on to the city, Bell Pond was used more or less, and particularly as an emergency supply, until about 1898, when it was finally abandoned.

The oldest supply of those now in use is that of Lynde Brook. This has a drainage area of about 2.92 sq. miles and a storage of 700 581 000 gal. From this reservoir is taken all the high-service supply for the city, through the main gatehouse near the lower end of the reservoir. Some distance up the easterly side of this reservoir is another gatehouse controlling the flow through a 30-in. conduit to Parson's reservoir, a distributing reservoir at the same elevation as the low-service reservoir No. 2 of the Tatnuck system. Through this connection the waters of Lynde reservoir may be used for the low service also, the prevailing practice being to take a limited portion of the low-service supply from this source as well as all of the high service. There are likewise several gated cross-overs about the city by means of which the high service can be connected with the low service.

To the west of the Lynde Brook watershed is that of Kettle Brook. This watershed has an area of about 3.62 sq. miles, the storage of which has been developed by four reservoirs with a

combined capacity of 812 362 000 gal. The lower one of these, Kettle Brook No. 1, is connected to the Lynde Brook reservoir by a 30-in. conduit, through which all utilized waters of the Kettle Brook watershed flow.

Draining into Kettle Brook Reservoir No. 1 from the west, but without any independent storage, is Peter Brook, having a drainage area of 0.48 sq. miles. This brook formerly drained into Kettle Brook some distance below the reservoir but is now diverted so as to feed into Worcester's supply. These three brooks combined give a total drainage area of 7.02 sq. miles, with a storage of about 1 512 943 000 gal., all available for Worcester's high-service system and also capable as above described for the low service when needed, being to some extent usually so used.

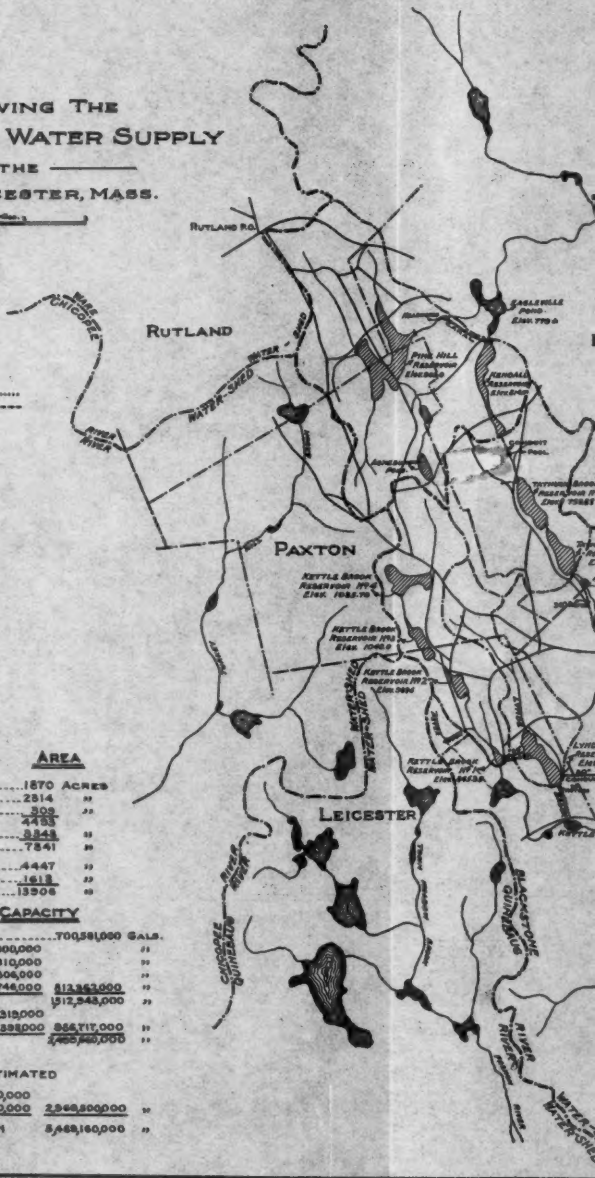
To the northeast of the Lynde Brook watershed is that of Tatnuck Brook, sometimes called the Holden supply from the town in which it is principally situated. This is used solely for the low service of Worcester, and has a watershed area of about 5.23 sq. miles, with a developed storage by means of two reservoirs of about 986 717 000 gal. without the use of flashboards. Eighteen-inch-high flashboards are sometimes used in the overflow of these two reservoirs only, and when so used, increase their capacity by about 91 190 000 gal. Together, these two systems have a combined watershed of about 12.25 sq. miles with a developed storage when flashboards are used of about 2 590 850 000 gal. and at this time constituted the entire water supply of Worcester.

An examination of a topographical map of this region will show that Worcester is situated in a comparatively high altitude and very close to the divide separating the various watersheds of Eastern Massachusetts. It has, therefore, a somewhat limited area from which to draft a water supply without pumping against high heads. About eight miles northwesterly from the city, in the town of Paxton, is the summit or apex of four different watersheds, where head: Turkey Hill Brook, draining generally in a southwesterly direction into the Chicopee River; Town Meadow Brook, draining southerly into the Quinebaug River; Tatnuck, Lynde and Kettle brooks, draining southeasterly into the Blackstone River; Asnebumskit and Kendall brooks,

Map Showing The Sources of the Water Supply for the City of Worcester, Mass.

Scale of Miles

Notes:
High Service lines shown thus .....
Low " " " " ----------

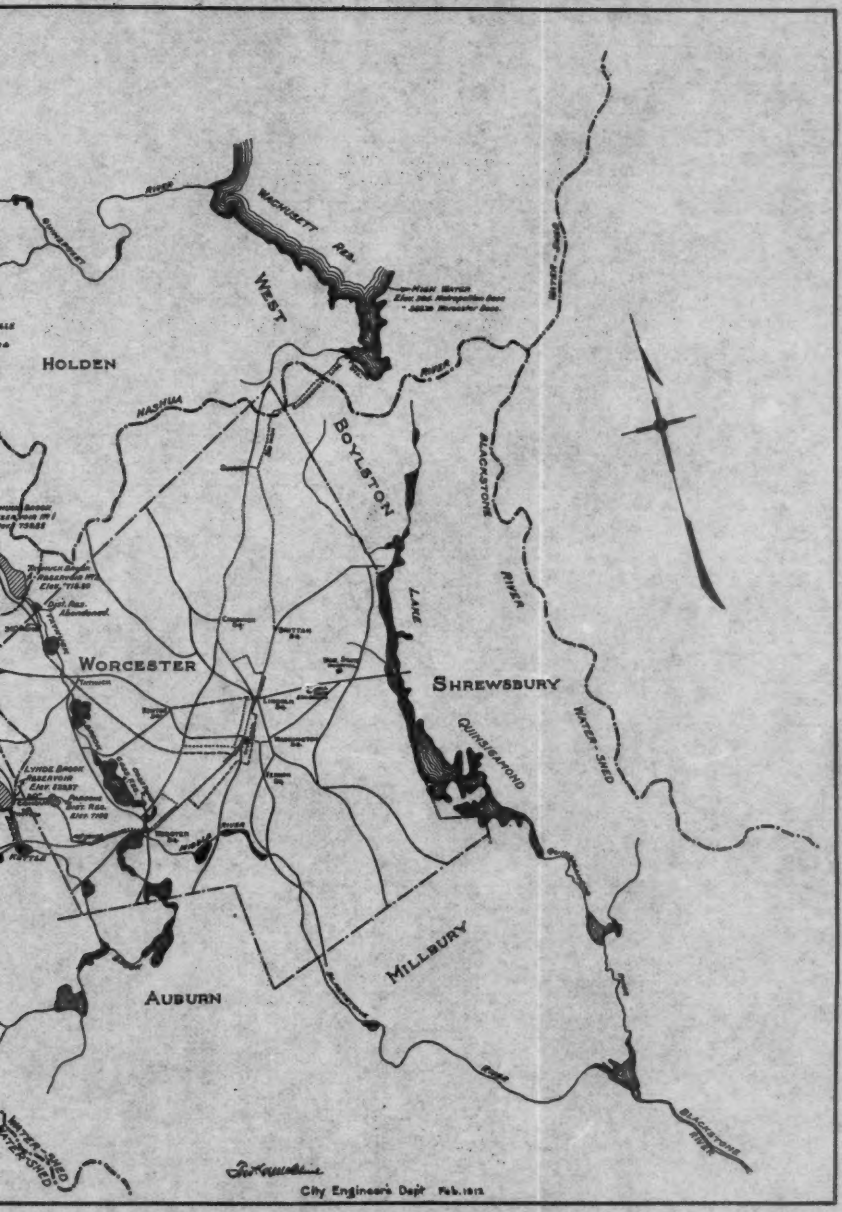


Water Shed			Area
High Service	Lynde Brook	1870	Acres
	Kettle "	2814	"
	Peter "	309	"
		4993	
Low Service	Tatnuck "	3848	"
	Total Developed	7841	"
Additional Supply	Asnebumskit Brook	4447	"
" "	Kendall Reservoir	1618	"
Total Developed and under Construction		13906	"

Reservoirs				Capacity	
High Service	Lynde Brook			700,581,000	Gals.
	Kettle	"	#1	12,000,000	"
	"	"	2	127,810,000	"
	"	"	3	152,806,000	"
	"	"	4	518,746,000	813,362,000 "
					1,512,543,000 "
Low Service	Tatnuck Brook	#1		729,319,000	
	"	"	2	257,398,000	986,717,000 "
	Total Developed Storage				2,499,260,000 "

Additional Supply Estimated

Kendall Reservoir	814,800,000		
Pine Hill "	2,155,000,000	2,968,800,000	"
Total Developed and under Construction		5,468,160,000	"


WEST
HOLDEN
NASHUA
RIVER
BOYLSTON
BLACKSTONE
RIVER
LAKE
WORCESTER
SHREWSBURY
QUINSIGAMOND
WATER-SHED
MILLBURY
AUBURN
BLACKSTONE
RIVER
City Engineer's Dept Feb. 1912

draining northerly and easterly into the Quinepoxit River and forming part of the watershed of the south branch of the Nashua River, which in turn, by means of the dam just above Clinton, forms the Wachusett Reservoir, supplying the larger part of the Metropolitan water for Boston and vicinity.

Another watershed, that of Ware River, heads in the town of Rutland, just to the north of Paxton and to the west of the Nashua River watershed.

These are all shown on Plate II and indicate better than can any description the extent to which Worcester had to this date developed all water supplies within what may be termed its territory.

Foreseeing, however, the ultimate necessity of going beyond the Blackstone River shed for an additional supply, Worcester had retained, in Chapter 488 of the Acts of 1895, the original act creating the Metropolitan Water District, the right to take water from the Nashua River watershed under certain conditions. This right was extended and amplified by subsequent legislation in 1897 and again in 1902 when, by Chapter 351 of the Acts of that year, authority was expressly granted to Worcester to take the waters of both Kendall and Asnebumskit brooks under the conditions contained in said Act. Proceeding under the terms of this legislation, while no legal taking of the water had then been made, more or less construction work leading to the development of these sources had been done at this time. Both Kendall and Pine Hill reservoirs as they formerly existed were storage reservoirs, built and maintained by the mills on the streams below, and before being disturbed by the city had estimated capacities of 82 000 000 and 119 000 000 gal. respectively. To this time in connection with the general plan for using these waters, Worcester has constructed a receiving pool, discharging into the head of Tatnuck Brook, a conduit, built partly in tunnel and partly in open cut, through the divide, to and through a gatehouse in a dike, also built at the southerly or upper end of Kendall Reservoir. This dike was required for the purpose of raising the water level higher than the natural divide between the two sheds and providing more storage than otherwise would have been available. The conduit through this dam continues about half way through Kendall Reservoir.

Above Kendall Reservoir and about half way between Pine Hill Reservoir and Eagleville Pond, a diversion dam and headworks have been built across Asnebumskit Brook, and an open conduit or canal, lined with concrete, constructed from these headworks to Kendall Reservoir, into which it discharges.

To digress at this point, it may be stated that the Asnebumskit and Kendall watersheds combined, which will thus be utilized, cover about 9.48 sq. miles, and will, when developed, with the existing watersheds, give Worcester a watershed area of 21.73 sq. miles to draw from. The present plans contemplate the building of a dam at the northerly end of Kendall basin, near the present outlet of Kendall Brook (this dam being at the present time, March, 1912, partially completed) and of a height to materially increase its former storage capacity, together with the extension of the conduit or channel through the reservoir so that it may entirely drain through the divide into Tatnuck Brook. Later and as a part of the same general scheme, it is intended to develop the Asnebumskit Brook watershed by the construction of a new dam near but a little above the site of the present one at Pine Hill and with a flow line at elevation about 902, taking the waters so stored through the channel of the brook to the headworks above outlined, thence through the open channel or canal, discharging into Kendall Reservoir and from there through the conduit into the head of the Tatnuck system. These improvements are expected to give Worcester an additional storage capacity in Kendall Reservoir of about 814 500 000 gal., and in Pine Hill Reservoir of about 2 155 000 000 gal. When completed, Worcester will thus have a total storage of 5 469 160 000 gal., without the use of flashboards, which with its then combined watershed of 21.73 sq. miles should be ample for a population of considerably over 250 000.

On July 1, 1911, the city had in its low-service or Tatnuck reservoirs, about 245 000 000 gal., of which about 225 000 000 gal., were available. On the same date in the Lynde and Kettle Brook reservoirs, the high-service system, were about 749 000 000 gal., 351 000 000 being in the Kettle Brook and 398 000 000 in Lynde Brook reservoirs. Of this quantity about 714 000 000 gal. could be drawn for use. On August 5, as above stated, the total quantity in storage was about 660 000 000 gal., thus showing a loss of 334-

FIG. 1.
HOLDEN NO. 1, FROM UPPER END, SOUTHERLY, AUGUST 1, 1911.

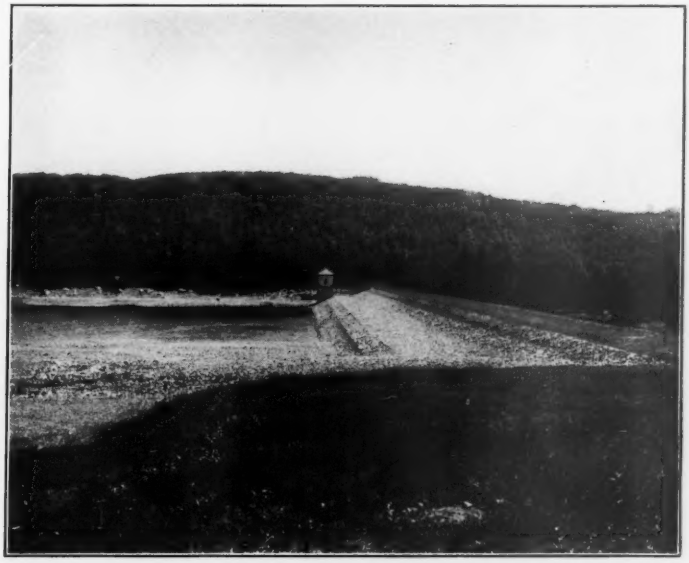


FIG. 2.
HOLDEN NO. 1. LOW WATER AT DAM, JUNE 8, 1911.
Views showing depletion of reservoirs.

000 000 gal. in thirty-six days, or an average of about 9 300 000 gal. per day.

During the month of June, the city had used, in round numbers, 333 000 000 gal., a daily average of 11 100 000 gal.

Thus facing a draft of between nine and ten million gallons per day in excess of yield, on July 1 it was apparent to anyone that Worcester might easily be out of water by October 1st to the 15th. To the mayor, the city engineer and the water commissioner it had been evident long before this time that unless relieved by rains, Worcester was facing a water famine. For several years prior to this date, both the city engineer and the water commissioner in their yearly reports had recommended that steps be taken to permanently augment the supply, and to this end not only had complete plans been prepared but work had been carried forward along the lines of such plans to the extent above outlined, — all that could be done with the means provided therefor. The work had not, however, at this time progressed to a point where it rendered available any addition in quantity to the supply although some considerable portion of the work then completed was of very great assistance in handling certain of the emergency supplies furnished the city later.

The first real official recognition of the existence of an emergency in the water supply by the City Council was made on June 26, when it instructed the water department to take all necessary steps to curtail the use of water, and particularly to see that all hose, street sprinkling, etc., was discontinued. This was done at once, a rigid inspection maintained, railroads were required to obtain their water at other places whenever possible, and such other steps taken as would insure the use of water for absolute domestic and business necessities only. Still the first week in July showed a drop in the storage of approximately 10 000 000 gal. daily. All waters in the upper reservoirs were drawn into the lower ones to reduce evaporation as much as possible. As a preliminary step looking to its use as a possible supply, although at that time having no legal right to the water, the mayor entered into an agreement with the owners of Pine Hill Reservoir not to draw down the water then in storage for the mills below but to leave it for the possible use of the city.

On July 10 the City Council authorized the city engineer and the water commissioner, acting under the direction of the mayor, to take the waters of Asnebumskit Brook, Lake Quinsigamond, and such other available source or sources as in their judgment the exigencies of the city demanded, procuring and erecting all necessary pumping and other machinery, pipes and appurtenances, etc., an appropriation being made for that purpose.

The city of Worcester for over thirty years has kept installed on the shore of Coes Pond, a pumping plant for use in any emergency that might arise, and in that period, although not for a number of years prior to this time, it had been so used. An order had been passed by the City Council as long before as December 28, 1910, to prepare the pumps at Coes Pond for use in case of necessity, and to erect such additional boilers and pumps as might seem desirable, which was done. Coes Pond and Reservoir combined were estimated to hold about 250 000 000 gal. of available water, and it was all along thought it could be used to help Worcester out of its troubles. On January 5, 1911, the State Board of Health approved the use of these waters in the event of a drought, although as a matter of precaution recommended that the inhabitants be cautioned to boil the water before drinking. This permission was reiterated by the board on March 28, and the officials of the city had been relying largely upon this source to relieve any stringency that might arise. However, so much public sentiment had been created against the use of this water that on July 20, at the conference before mentioned, the State Board of Health decided that this water could not be used except as a last resort, and as a consequence a complete change in plan was necessary.

Lake Quinsigamond waters could not be used directly from the lake on account of pollution due to the state hospital on the hill to the west, and also that due to the cottages and places of amusement surrounding the lake. Consideration, however, was given to driving wells near the shore, thus obtaining benefit of ground infiltration as well as of such water as might otherwise be obtained from the wells. The question of the installation of filter beds and other means of purification were likewise considered, but the time required for these latter schemes appeared to make them im-

FIG. 1.

UPPER END OF SLUICE AT END OF DODD ROAD, LOOKING NORTHERLY UP CANAL. AUGUST 1, 1911.

FIG. 2.

30-INCH DISCHARGE PIPE FROM PUMPING STATION ON WACHUSETT RESERVOIR, SHOWING TIE-RODS IN PLACE.

practicable, and as, in the experimental wells sunk, much rock, bowlders, etc., were encountered, it was finally decided to abandon further consideration of this source.

The waters in Pine Hill Reservoir being unhesitatingly approved by the State Board of Health, steps were taken at once to complete the channel in the upper end of Kendall Basin so as to permit of the flow of these waters to Tatnuck Brook. As the water could not be turned directly into Kendall Basin from the canal without flooding the construction work then in progress along the lines of the permanent plans, and as it also could not be held in the basin, with the old outlet dam removed and the new one not built, without considerable cofferdam work, it was decided by the city engineer, with the approval of the mayor, to build a wooden flume or sluiceway, following somewhat the contour of the basin, from the southerly end of the canal from Asnebumskit Brook to a point where the conduit from Tatnuck could receive the water and keep it confined within its banks, a distance of about 4 700 ft. Accordingly a contract was negotiated by the mayor on July 20, immediately after returning from the conference with the State Board of Health in Boston, for building the same. The sluiceway as designed had a safe carrying capacity of upwards of 8 000-000 gal. per day. This work was finished August 1, and on that day water from Pine Hill Reservoir was first let into Worcester's water system.

An examination of the ground and a report thereon by Prof. W. O. Crosby, geologist of the Massachusetts Institute of Technology, encouraged the city in the belief that water could be obtained from the basin of Kendall Reservoir by means of wells, and some sixty shallow wells of $2\frac{1}{2}$ in. pipe were driven in the bottom of this basin. These wells ranged from 24 to 32 ft. in depth, penetrating a coarse sand in nearly all instances. Two gasolene pumping engines were obtained, the wells connected up to these, and the water so obtained pumped into the same sluice which carried the waters from Pine Hill Reservoir. Pumping from these wells continued until about the first of October, when, a vacuum of from 22 to 24 in. being required to raise the water, pumping ceased and this source was abandoned.

When Mr. Allen assumed charge of the emergency work the

sluiceway had been built and the city committed to the driving of the wells in Kendall Basin. Believing as he did that with all the water then in sight, including the 119 000 000 gal. in Pine Hill Reservoir, such reserve as could be obtained from Asnebumskit Brook and Pond above Pine Hill and with what could be pumped from these wells, it all was likely to be exhausted before the Metropolitan supply could be made available, he further recommended to the mayor and through him to the City Council at its meeting on August 14, that authority to take the waters of Eagleville Pond be given, — this having an available estimated quantity in storage of about 240 000 000 gal.,—that pumping machinery be erected and a pipe line laid from this pond to the lower end of the canal on Dodd's Road, so called, where the wooden sluiceway joins this canal, to enable this pond water to be pumped into the flume. An appropriation of $21 000 was asked for this purpose, which was voted and the authorization to take the waters granted.

Thus, on August 14, only five days after his appointment, appropriations had been made, based upon plans and estimates worked out in that time by Mr. Allen with the writer's assistance, and the work ordered forward. It may at this time be pertinent to say that the Metropolitan job, so called, which of course was the important one, estimated to cost $153 000, actually did cost $153 626.29, as shown by the city auditor in his annual report to the City Council at the close of 1911, being within about four tenths of one per cent. of the estimate. This is mentioned only to emphasize the fact that although the time was extremely limited, the work was carefully planned, estimated, and then constructed in fairly good accord with such plans. It is further pertinent to state that while the general scheme was well in hand and inquiries had been made as to where and how soon some of the machinery, pipes, etc., could be obtained, none had been purchased nor contracts let at the time the appropriations were made and the final order given by the City Council to proceed with the work.

The Eagleville Pond supply was placed under the immediate charge of Mr. Samuel H. Pitcher, M. Am. Soc. C. E., formerly of the city engineer's office of Worcester, and a member of this Association. Three pumps, obtained from stock on hand of the

Deane Steam Pump Company, of Holyoke, Mass., were erected in an old power house of the Worcester Consolidated Street Railway Company, which was advantageously situated upon the shore of this pond. The Railway Company also had a couple of boilers at their Millbury power house, not then in use, which were of suitable size for this work, which they loaned to the city. These were erected in this power house, and thus at comparatively small expense a temporary pumping plant was installed. The pumping head including friction with all three pumps running was about 120 ft., the capacity being about 4 500 000 gal. per day.

A 12-in. force main was laid, about 4 900 ft. long, from this power house to the sluiceway as above described, about a third of the way being across private property and the remainder of the distance in Dodd's Road, so called. The larger part of this pipe was from the stock of the Worcester Water Department, supplemented by some found on hand at one of the foundries from which quick delivery was had. Several contractors were asked to submit bids for laying this pipe, two being received; but as the lowest of these was for $1.50 per ft., both were rejected and the Water Department laid it with their own force and at a cost of a fraction under fifty cents per foot. The entire work was completed and pumping began on September 27, twenty days after actual work was started on this job. The total cost of the Eagleville Pond supply, as given by the city auditor in his annual report, was $18 044.22, — $2 955.78 under the estimate.

From the moment of the passage of the necessary orders by the City Council on August 14, work proceeded as rapidly as possible upon the principal emergency job, known as the Metropolitan supply. While the matter had been discussed with them before the first of August by the mayor, and it was tacitly understood that permission would be granted by the Massachusetts Water and Sewerage Board to take water from Wachusett Reservoir, formal permission was not granted until August 28. Work, however, was not delayed on this account.

Within about 1 500 ft. of the selected location for the pumping station upon the shore of Wachusett Reservoir, and crossing the proposed pipe line were the high-tension lines of the Connecticut River Transmission Company, carrying electric current under

65 000 volts pressure. This was one of the controlling factors determining the use of electrical machinery to operate the power station, — other considerations being the lesser cost of first installation as compared with steam pumping engines, boilers, etc., smaller and consequently less expensive buildings and foundations, quicker delivery of machinery and more cleanliness in operation, — this latter factor being important particularly to the Metropolitan Water Board, owing to the location of the plant. Cost of operation by electrical power was not analyzed for this particular job, but was considered to be at least as cheap as steam power, owing to the distance coal would have to be hauled and the lesser amount of labor required to operate an electrically driven station than would be the case with a steam plant of the required capacity, which was about 1 500 horse power when pumping at a ten-million-gallon rate against a pumping head of 550 ft., these being the conditions to be met.

On August 15, the day following the authorization of the work, a contract was closed with the Alberger Pump Company of New York for 3 two-million-gallon, 4-stage turbine pumps, guaranteed to operate at this capacity against the full head of 550 ft. Shipment was promised of the first unit September 5, the second on September 9, and the third September 12, — all with a forfeiture and bonus clause. The average date of actual shipment was the exact contract date. The Alberger Pump Company also gave the city options on two additional pumps of the same type and at the same price, with a delivery of four weeks after receipt of order. Taking some chances on weather conditions, it was decided not to order these additional pumps until later, but this was the only departure from the full 10 000 000 gal. capacity required, in the machinery, pipes, etc.

On August 15 contract was entered into with the Connecticut River Transmission Company for power to the maximum demand of 800 k.w. with options under certain conditions to increase it to 1 300 k.w., this to be delivered at the pumping station in the form of 3-phase, 60-cycle, 13 200-volts alternating current. As the actual quantity of current desired was largely dependent upon weather conditions, no minimum rate or consumption was guaranteed, but in lieu of a minimum, the city agreed to pay for certain

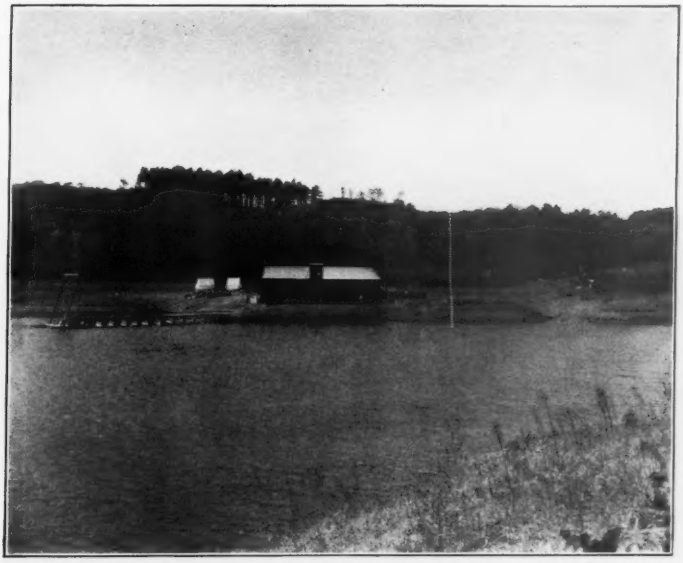


FIG. 1.
VIEW OF PUMPING STATION.

FIG. 2.
30-INCH CHECK-VALVE.

additional construction required to be done by the Connecticut River Company to carry out this contract, such to remain its property. The city also paid all costs of bringing the power from the company's lines to the pumping station.

On August 23 a contract was entered into with the General Electric Company to furnish the electrical outfit, consisting of 5 250-h.p. motors, with starting devices complete; 3 210-k.w. air-blast transformers; 2 blowers; 9 100-k.w. oil-cooled transformers; 1 lightning arrester equipment; 1 feeder and 5 motor switchboard panels. This material was to be shipped at varying intervals ranging from ten days to four weeks, except in the case of 1 blower requiring six weeks, 1 motor eight weeks, and the 9 100-k.w. transformers, ten weeks for delivery. All of this material was shipped and received as contracted for. To provide for transformers, — the only part of this apparatus that might cause delay, — an arrangement was entered into by the Connecticut River Transmission Company with Crocker, Burbank & Co., of Fitchburg, Mass., for the use by the city, for two months, of three large transformers they had, suitable for this work, thus tiding the city over the delay incident to receiving its own.

On August 24 a contract was signed with the Stone & Webster Engineering Corporation, to erect and install the pumping machinery complete, including the building, suction pipes, intake chamber and screens, and all discharge connections to the outside of the building. This covered also the preparation of the plans of the electrical installation and the inspection, etc., of the machinery furnished, all subject to Mr. Allen's general supervision. Under this contract ground was broken on September 12 at the pumping station, and on October 22, forty days thereafter, water was being pumped with everything in complete working order.

Coming now to the pipe line, on August 16, a contract was entered into with F. A. Houdlette & Son, Inc., of Boston, to furnish all cast-iron pipe and special castings required, including all flanged work at the pumping station. This contract called for 12 600 ft. of 30-in. pipe of classes D, F, and H of the New England Water Works Association Standard Specifications; 480 ft. of 24-in. Class D pipe; and 1 500 ft. of 12-in. pipe of Classes C and H. Shipment was to commence August 19, and to average 1 200

ft. per day until the entire quantity was shipped. It should be borne in mind that all this pipe had yet to be cast except about 173 lengths already on hand, which the city agreed to accept. The specials and flanged work were to be shipped within three and four weeks after receipt of specifications. The first shipment of pipe was made on August 17, one day after signing the contract, and the last shipment (except two cars shipped September 14) on September 8. The first car to arrive at Worcester was on August 31, and the last car September 27. Some few special castings came later but did not materially delay the work.

On August 18, contract was closed with the Builders Iron Foundry, of Providence, R. I., for a 30-in. Venturi meter, with 10-in. throat, together with a combined register-indicator-recorder, all to be delivered within four weeks. This meter was necessitated by the agreement with the Metropolitan Water and Sewerage Board, which required payment for all water taken by the million gallons. This meter arrived in Worcester two days ahead of schedule time. When setting the Venturi tube, it was discovered that the two sections on the outlet end were defective. This discovery was made just as they were about to be placed in the pipe line one Wednesday afternoon, at about three o'clock. By the use of the telephone, supplemented by a trip of the writer to Providence that night and a personal conference with the officials of the foundry, these two specially designed castings, for which patterns had to be made, were put through and delivered to a motor truck on the following Saturday evening and delivered on the work on Sunday morning, being set in place that same day.

This was only one of the numerous uses made of auto trucks as well as of automobiles in the prosecution of this work. The automobile used by the engineers had a record of over 3 600 miles in a little under ten weeks' use, frequently being employed from twelve to fifteen hours of the day. Its use undoubtedly more than doubled their radius of action, and to-day this means of locomotion is well-nigh indispensable under modern construction methods.

On August 21, a contract was closed with the Chapman Valve Company for 3 30-in., 1 24-in., 3 12-in. flanged, and 5 6-in. blow-off gates, all to be delivered within three weeks, which contract likewise was fulfilled on time.

On August 19 a contract was made with the Ludlow Valve Company for 1 30-in. swing-flap check valve; 3 12-in. extra heavy check valves for working pressure of 240 lb., and 3 12-in. foot valves for the suction pipes, also to be delivered within three weeks. On August 22 a contract was closed with the same company for 1 30-in. check valve, to be built for a working pressure of 230 lb., to be delivered in as much under six weeks as possible. In connection with this check valve, which weighed 13 900 lb., was another of the quick movements of the job. All of the pipe and most of the other carloads of freight had come over the Boston & Maine Railroad, and several times delays had occurred which had caused the question of deliveries to be taken up direct with the superintendent of that division of the railroad. About a week before this check valve was ready to ship, acting upon information from the factory, we notified the superintendent that it would be delivered to his road at Troy, N. Y., on Saturday afternoon, September 30, and that it was wanted as quickly as he could get it to us. It was loaded at Troy that Saturday at about 3 P.M. and at six o'clock on Sunday morning it was in the Worcester freight yard. While this was the quickest freight delivery on this job, — possibly it is safe to say on any other as well. — still it was only one of many acts which contributed to hurry forward the work, not alone on the part of the railroads but of all others connected with the job.

On August 15, specifications having been prepared, proposals were invited for teaming and laying the pipe and appurtenances. While these were not advertised owing to lack of time, six parties thought to be equipped to handle this work were asked to bid. From these four bids were received and opened on August 18. These ranged in amount from that of E. D. Ward, of Worcester, who was the lowest bidder and to whom the contract was awarded, at $34 605, to the highest bid of $52 350. Mr. Ward, while a contractor of large experience in building work, excavations, etc., had never laid any pipe, and for this reason alone there was some question as to his ability to carry forward the work in the time allowed for it. However, it was finally decided to award the contract to him, largely, perhaps, because — from the nearness in price of all the other bidders as well as the amount of their bids,

nearly fifty per cent. above the engineer's estimates — it looked as though there might be a combination among them. At the close of the work, whatever may have been the opinion at the start, there was no question but that this contract had been wisely awarded.

This contract required the work of laying pipe to begin within forty-eight hours after the first carload arrived in Worcester, and to average laying complete nine hundred feet per day. The contractor did not keep up with this schedule, as rainy weather interfered with the work soon after he was well started. In this case, as each day's rain gave Worcester from two to four days additional water supply, such causes of delays were blessings than otherwise. Had the weather been as dry in September as it was in June and July, this work, finished as it was in record time, could have been done in at least two weeks less time. With a rainfall in August of 5.15 in.; in September, 4.10 in.; and in October of 5.48 in., it seemed as though as soon as the city was tied up in contracts and the work under way, rain was almost interminable.

Mr. Ward broke ground August 28, and laid the last piece of pipe October 16. October 17 to 19 were employed in filling the pipe line, when a cracked pipe developed. This was replaced and proved to be the only defect in the entire work. The line was completely filled by the 21st; machinery and pipes were tested out by the pumps on the 22d; and on the 24th of October, in the presence of the mayor, members of the City Council, and others interested in the work, the pumps were officially started by Mr. Frederick H. Lucke, chairman of the water committee of the City Council. It was found that by running one pumping unit, a capacity of about 3 000 000 gal. was obtained; with two units, about 5 000 000 gal., and with the three units, about 6 500 000 gal., thus somewhat exceeding the requirements. Quite likely had all five of the units contemplated been erected and operated at the same time, the additional friction head would have reduced the output to about the 2 000 000 gal. average for which they were guaranteed. The observed pressures when operating were respectively, 187, 204, and 218 lb., with one, two, and three units running.

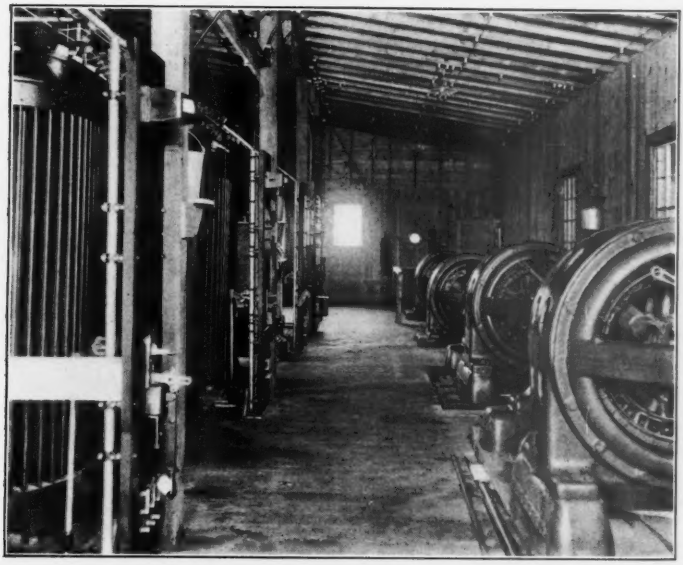


FIG. 1.

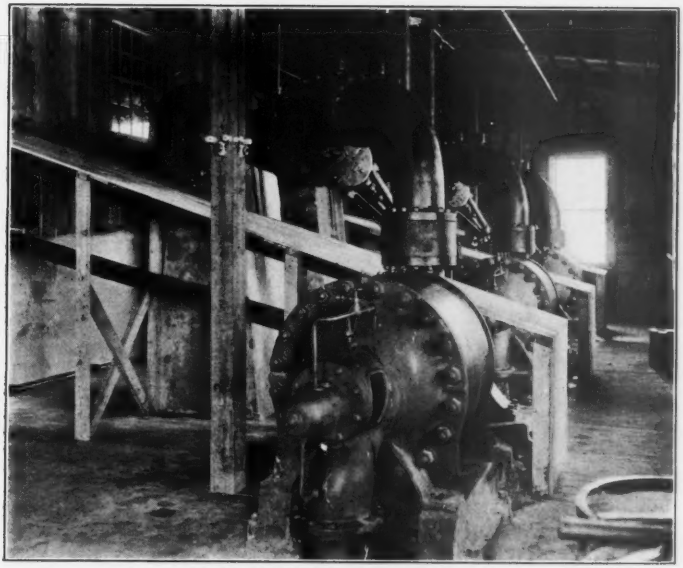


FIG. 2.

INTERIOR VIEW OF PUMPING STATION, SHOWING MOTORS AND PUMP.

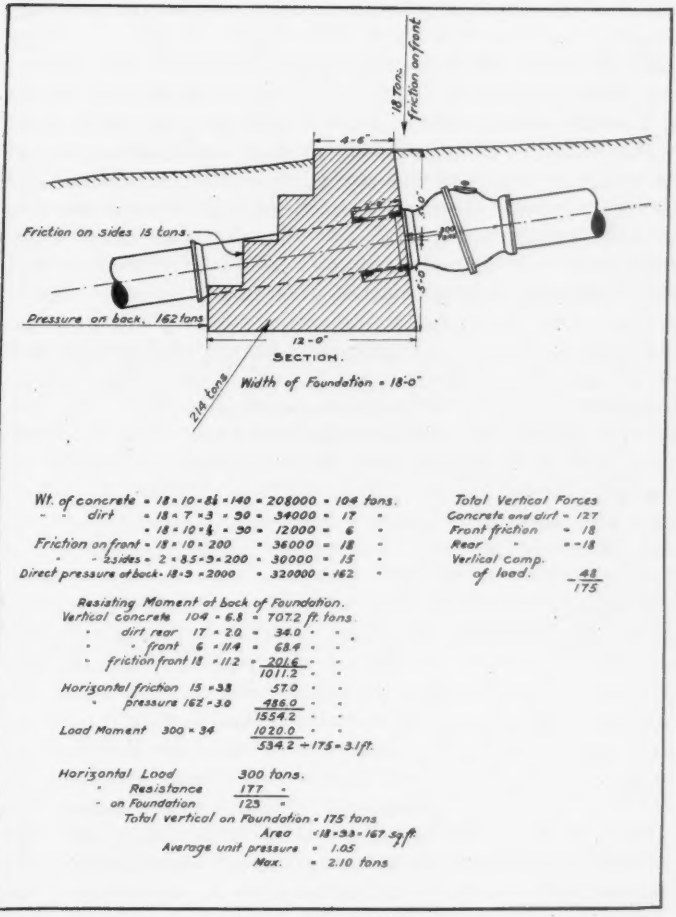
Thus, in two months and ten days after the City Council made the appropriations for this work, it was in excellent running order. As before stated, had weather conditions been favorable and thus required it to have been done, the time could have been shortened to somewhat under sixty days. As it is, when the capacity and weight of the work is considered, it is perhaps a safe assertion to make that it was one of the quickest jobs on record, if in fact it did not break all records. Every one took an interest not only in the work itself but in attempting to make it a record job, and its success is largely due to the lack of friction of any kind between the engineers and contractors. No hair-splitting questions were raised on either side, and whenever difficulties presented themselves they were solved with the one idea of good work and expedition, while the question whether or not it would add to or take away from the profits of any particular contract was not considered or thought of. This job also is a good illustration of what can be accomplished when construction work is unreservedly placed in the hands of engineers unhampered by outside considerations. Civil service rules and city ordinances regulating the employment of labor or the letting of contracts were suspended for this work, and Mr. Allen was given free rein to proceed as he choose; in fact, it was only upon these conditions that he accepted charge of the work. Mayor Logan also fully supported him in all questions arising, thus materially assisting in preserving a full degree of harmony during the progress of this and other portions of the emergency work.

There were only a few engineering problems of moment connected with this work, and these hardly worthy of mention. The use of centrifugal pumps, belt connected to electrical motors and operated under the extreme head it was here subjected to, is certainly unusual in water-works practice, yet in this case it seemed to be a satisfactory combination. In ordering the pipe, knowing from experience that in pipe of this diameter more or less of it was certain to be cast eccentric as to thickness of shell, and further realizing that rejections must be limited to the least quantity consistent with obtaining satisfactory results on account of the limitations in time, the pipe was specified about one class heavier than otherwise might have been used. Even then care

was taken in sorting out all pipe as it arrived and distributing it in accordance with its actual thickness of shell on the thinnest side, rather than by its normal class or weight. With an elevation of the pipe line at the reservoir of about 380 and of about 692 where it crosses the divide between the Nashua and Blackstone watersheds, there was sufficient range of pressures to care for about all the varying thicknesses of pipe that arrived. While this method is not economical in ordinary work, its adoption here saved considerable time on this job.

Two 30-in. check valves were used on this line, — one at Summit to avoid emptying Worcester's piping system in case of a break in the 30-in. line, and another near the pumping station to guard against a serious washout in case of accident to the pumps or to the pipes within the building. This latter check valve was set only about 26 ft. from a 45-degree bend where the pipe changes its horizontal direction so as to approach the pump house. To properly anchor this check as well as the pipe line itself at the foot of a rather steep hill, and to take the thrust of any water hammer off the bends, the pumps, and the discharge header within the pump house, a steel grillage or framework was designed and built by the Eastern Bridge and Structural Company, of Worcester. This framework was about 18 ft. long and was set at right angles with the pipe line, being about 2 ft. 10 in. wide along the line of the pipe. It consisted of two girders, one above and one below the pipe, connected together by an octagonal grouping of I-beams so spaced that, with an opening just large enough for the barrel of the pipe to pass through, it engaged the bell of the check valve in nearly all of its circumference. This framework was solidly jacked against the face of the bell of the check and the whole firmly anchored in place by mass concrete. The pressure against this check, when pumping at the rate of 10 000 000 gal. per day was assumed to be about 75 tons, and, to allow for water hammer due to a sudden interruption of the power, the stoppage of the pumps, the blowing off of a bend or from any other reason, the anchorage was designed to withstand four times that pressure, or 300 tons.

All bends, both horizontal and vertical, were thoroughly supported and embedded in concrete, those at and near the pumping



Wt. of concrete	= 18 × 10 × 8½ × 140	= 208000	= 104 tons.	
" " dirt	= 18 × 7 × 3 × 90	= 34000	= 17	"
	= 18 × 10 × ½ × 90	= 12000	= 6	"
Friction on front	= 18 × 10 × 200	= 36000	= 18	"
" 2 sides	= 2 × 8.5 × 3 × 200	= 30000	= 15	"
Direct pressure at back	= 18 × 9 × 2000	= 320000	= 162	"

Total Vertical Forces	
Concrete and dirt	= 127
Front friction	= 18
Rear "	= -18
Vertical Comp. of load.	48 / 175

Resisting Moment at back of Foundation.

Vertical concrete	104 × 6.8	= 707.2 ft. tons	
" dirt rear	17 × 2.0	= 34.0	" "
" " front	6 × 11.4	= 68.4	" "
" friction front	18 × 11.2	= 201.6	" "
		1011.2	" "
Horizontal friction	15 × 3.8	57.0	" "
" pressure	162 × 3.0	486.0	" "
		1554.2	" "
Load Moment	300 × 3.4	1020.0	" "
		534.2 ÷ 175 = 3.1 ft.	

Horizontal Load	300 tons.
" Resistance	177 "
" on Foundation	123 "

Total vertical on Foundation = 175 tons
Area = 18 × 9.3 = 167 sq. ft.
Average unit pressure = 1.05
Max. = 2.10 tons

FIG. 6.

CONCRETE ANCHORAGE FOR STEEL FRAME BRACING TO 30-INCH CHECK VALVE.

station being tied together with clamps, rods, and collars, proportioned to take about double the strain due to the full pumping head.

The Boston & Maine Railroad was crossed twice underneath, and, owing to its requirements as to cover, it was necessary to go to a depth of about 8 ft. to the bottom of the pipe, under their tracks. This in one place, owing to steep banks on the side of their right-of-way, required a cutting of upwards of thirteen feet. In both crossings, water was encountered, and in the deeper one a rather quick-running sand gave the contractor considerable trouble. No interruption of trains was allowed, and the work was carried forward to the satisfaction of all concerned.

This article would not be complete without mention of the work done by the water department of the city while this job was under way. To enable the city to avail itself of this supply, numerous changes in and additions to the pipe lines in the city between Summit and Lincoln Square had to be made, and while these were all in harmony with the well-designed piping plan of the city, except for this purpose all these changes would not have been made for a year or two at least. Between August 14 and October 21, the water department with their own forces laid about 12 860 ft. of 16-, 20-, and 24-in. pipe for street mains, practically the same quantity in length as was laid under Mr. Allen's direction from Wachusett Reservoir to Summit; this in addition to that laid by them on the Eagleville Pond line and also in their regular work, which was not materially interfered with. While this in itself would be something of a stunt for most of us, still those who know the capacity for work of our President can easily understand that with him it was simply good exercise. He also was of great assistance at all times to the various contractors as well as to the engineers, and never was so busy that he could not find time to help them out of their difficulties. To him is due the credit for a large measure of the success of the enterprise.

The pipe line work was under the immediate charge of Mr. Arthur E. Tucker, of the city engineer's office, who also by his handling of the work, particularly with a contractor new to pipe laying, is deserving of much credit.

The city as well as the engineers feel under great obligations to the Stone & Webster Engineering Corporation for options on machinery, pipe, etc., which they turned over to the city without cost, and also for their assistance in every way possible in the carrying out of the work.

Owing to the heavy rains which prevailed during October, it was not necessary to use the supply from the Metropolitan source to any extent, and after it had been thoroughly tried out, pumping about 60 000 000 gal. into Worcester's system, it was shut down and now remains in place, awaiting such other uses as it may be put to. In his address to the City Council at the close of his term of office, on December 27, 1911, Mayor Logan among other things said:

"I now offer the suggestion that this pipe line be not taken up, but that the pumping plant and pipe line be kept intact and ready for use as an insurance in case of necessity to strengthen the high-service system. If this is not done, the city must begin at once to consider other sources of supply to strengthen the high-service system, which means a large expenditure of money. If an arrangement can be entered into with the Metropolitan Water Board to allow this pumping plant to remain, the city of Worcester may not be obliged to add to its high service for many years to come, and the interest on present investment for an emergency supply will be as nothing compared to the interest charges which the city must provide for if obliged to build additional reservoirs and construct pipe lines to connect with our present high-service system."

It may thus happen that the full value of the work will be repaid to the city, even though it has not yet been necessary to utilize it to any considerable extent.

Nevertheless, based simply upon its proposed and intended use, it can hardly be said that the work was otherwise unnecessary, as the conditions in August and earlier demonstrated the need of just such insurance. The records at Lynde Brook showed, from January 1 to July 1, 1911, a rainfall of only 15.19 in., — lower than during any corresponding period for years. Further, it may be interesting, as showing what would have happened to Worcester had none of the emergency supplies as furnished been availed of, to call attention to the quantities so yielded to the close of

October, when the rains made further contributions f ide sources unnecessary. These quantities were:

From Pine Hill Reservoir and Asnebumskit Brook	585 000 000 gal.
From wells in Kendall Basin	60 000 000
From Eagleville Pond	62 000 000
A total of	707 000 000 gal.

On October 15 the Worcester reservoirs had

In the two Tatnuck reservoirs	120 000 000 gal.	
In the four Kettle Brook reservoirs	103 000 000	
In the Lynde Reservoir	309 000 000	
A total of		532 000 000
Being less by		175 000 000 gal.

than the emergency supplies had furnished.

Had the months of September and October been as dry as all indications earlier in the season pointed to, Worcester's reservoirs, in spite of all the contributions they could have received, would have been very close to empty when the Metropolitan supply could have been ready for use.

DISCUSSION.

THE PRESIDENT. The water department and the city engineer's department had tried for many years to get an appropriation sufficient to provide this new water supply, but the progress had been very slow. It was hard to awaken the public conscience to the necessity of increasing the supply, so long as water continued to run from the faucets. But conditions had reached such a point, during the fall of 1910 and the winter of 1911, that the speaker was unable to take his regular morning bath with any comfort. Mr. Kimball came to Worcester and assured me that I could do so, but while I believed fully in him I did not do it until I saw that something was doing on the Metropolitan System. It took a long time to get a start. I think for something like seven or eight years we had been trying to get an appropriation,

and I doubt very much if the work would have been carried on as far as it has at the present time if it had not been for the shortage of water in 1911. I think the work of developing the emergency supply was done in remarkably quick time, and it shows how men of ability, unhampered by Civil Service rules and, I might say, by politics, can go ahead, when sufficient appropriations are made, and prosecute a work. We are maintaining the pumping plant at the Wachuset Reservoir in condition for operation, and shall do so probably for a year or more, until we have more fully developed our present supply.

THE ECONOMY OF CIRCULAR REINFORCED CONCRETE RESERVOIR CONSTRUCTION.

BY ALEXANDER POTTER, C. E.

[*Read by title, February 14, 1912.*]

The economy in constructing service reservoirs, circular in shape, for water-works purposes is not, in the opinion of the writer, appreciated as fully as it should be. The circular shape for small reservoirs is not only the safest type of construction from a structural standpoint, but permits also a more economical use of the structural materials. Among the many and, unfortunately, only too frequent failures in reinforced concrete construction, it is rare to note failures of circular reinforced concrete tanks, other than those of badly leaking tanks due to either poor workmanship or poor design, or both.

One of the greatest advantages possessed by the circular section and not possessed by any other is the ability to increase economically the capacity of such a reservoir by simply increasing its depth. This is of great importance in the design of water-works improvements, for it enables the designer to keep down the first cost of construction by building a reservoir of a size sufficient for the immediate needs. As the water consumption increases, it is possible to increase economically the capacity of the reservoir, and at the same time raise the water level to counteract the increasing frictional losses in the distribution system due to increased consumption.

The design of a circular reinforced concrete reservoir appears to be so very simple that the inexperienced designer, carried away by his enthusiasm, is apt to create a structure of larger diameter than the application of the simple formula of tank design would seem to warrant. To him there appears to be no ostensible reason why a structure twice the size of one already built should not offer every evidence of strength and stability if designed in

accordance with the formula for ring tension,— a very misleading deduction. The secondary stresses, which in small structures are insignificant, and consequently deemed of too little importance to have attention called to them, increase rapidly with the size of the structure, and only too often limit the size to which any particular type of construction can be adapted.

In a circular reinforced-concrete tank, the writer has in mind the varying tension from point to point in the steel reinforcement due to the difficulty of obtaining a true circle in the field. In a small tank, this is not so serious, as its effect upon the resultant stresses in the steel reinforcement is so slight. To make this point clear, some computations have been made by the writer based on the assumption that in the construction of this type, even with the best of care taken in the field, a variation of a half-inch in the middle ordinate of a 10-ft. chord is likely to occur.

Radius of Tank.	Variation in Radius of Curvature due to a Variation of 1/2 in. in Middle Ordinate of a 10 Ft. Chord.	Corresponding Range of Tension in Steel Reinforcement. Average Unit Tension equals 14 000 Lb. per Sq. In.
Feet.	Feet.	Pounds.
25	23.0– 27.2	12 860–16 200
50	42.8– 60.1	11 950–19 100
100	74.9–150.5	5 910–21 100
200	120.2–632.0	5 820–44 500

This table is not made to accurately show the variation in the tensile stresses of the steel reinforcement for the various diameters given; it does, however, give a fair idea of what may be expected in the variation of the ring tension in a circular structure. It points out the danger resulting from carelessness in constructing a circular reservoir of comparatively thin wall section more than 100 ft. in diameter. For reservoirs of large diameter, however, the economy resulting from the use of a circular section does not obtain to the same extent, and consequently recourse to this type is not so frequent.

The writer's experience would tend to limit the working tension in the steel reinforcement to 14 000 lb. per sq. in. in a small tank, and to 12 000 lb. per sq. in. for comparatively large tanks. A reduction in the allowable steel tension for large tanks is recommended because of the greater range in the ring tension present in the larger structure. It may even be advisable to reduce the allowable unit stresses below 12 000 lb. per sq. in. to keep the excessive local stresses which cannot be avoided within safe limits.

The variation in the tension of the steel reinforcement from point to point, due to the varying curvature of the shell, makes the use of a reinforcing bar with mechanical bond advisable. The reinforcing bars for this reason should also be of as small a size as it is possible to handle economically in the field.

A high carbon steel with an elastic limit of 50 000 lb. per sq. in. can be used to great advantage.

Another difficulty to be considered in the design of a circular reservoir is the tendency to rupture along the line between the inside wall of the reservoir and the base, due to the expansion of the walls by internal water pressure and the consequent drawing away, as it were, from the base of the tank.

A good example of increasing the capacity of a circular reservoir is the enlargement of the distribution reservoir for the village of Suffern, N. Y. This village takes its water supply from Anthrim Lake, formed by impounding a branch of the Ramapo River. The water is pumped from this lake to a distribution reservoir located on the side of a mountain to the north of the village, about 180 ft. above the average village datum. This distribution reservoir, built a number of years ago, is a circular tank 70 ft. in diameter and 10.5 ft. deep, sunk entirely into the ground. The walls forming the sides of the tank are 2 ft. thick, and both bottom and sides are constructed of plain concrete. This reservoir had a storage capacity of 266 000 gal., and cost approximately $4 000.

The recent growth of the village has made it advisable to double the capacity of this distribution reservoir. The old structure, although massive, nevertheless leaked to a considerable extent, especially in the bottom. It was, therefore, decided to line the bottom of the tank at the same time that the sides were being

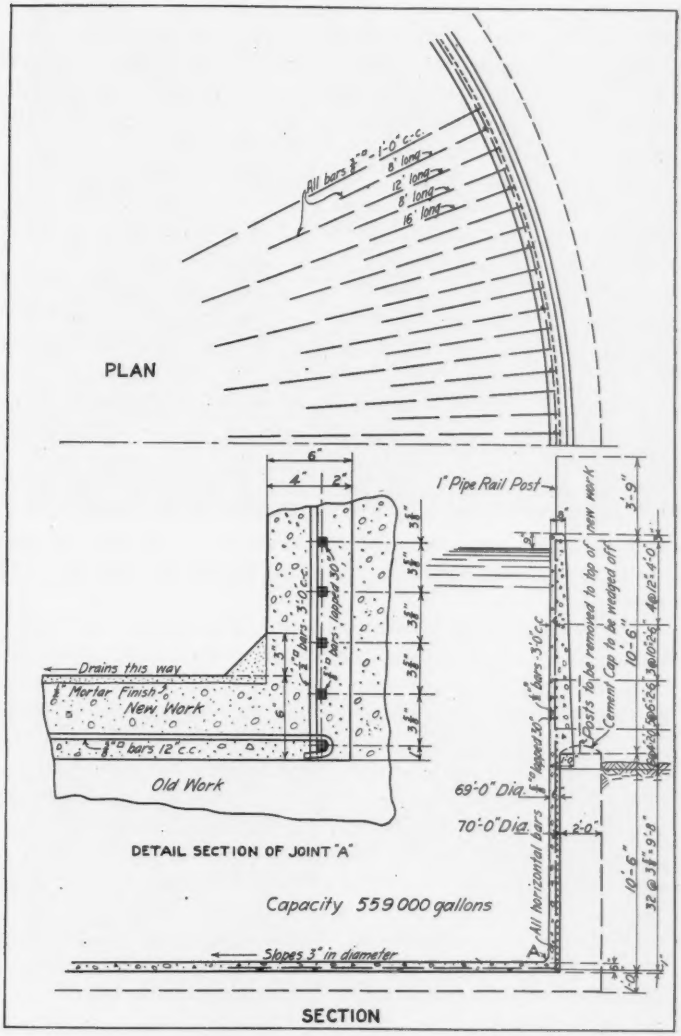


FIG. 7.

RESERVOIR AT SUFFERN, N. Y.

raised. The reservoir as remodeled has an inside diameter of 69 ft. and holds approximately 20 ft. of water, giving a storage of 559 000 gal. The side walls of the old tank are lined on the inside with 6 in. of reinforced concrete. Above the old work, the width of the new work is 12 in., tapering to 8 in. at the top. (Fig. 7.)

The circumferential reinforcement consists of $\frac{5}{8}$-in. square corrugated bars, possessing an elastic limit of 50 000 lb. per sq. in. These bars are so spaced that the average unit tensile stress in them does not exceed 14 000 lb. per sq. in.

In designing the lining for the old reservoir, it was assumed that the reinforcement would only have to take care of the increased tension due to the additional depth of 10.5 ft. This is a constant quantity with a full reservoir; consequently the spacing and size of the steel in the lining of the old reservoir is uniform. The existing wall is still relied upon to resist the hydrostatic pressure that it formerly did.

It is not very likely, because of the great daily fluctuation in the water level in this reservoir, that ice pressure will develop to such an extent as to seriously over-stress the reinforced concrete shell, and consequently, no provision has been made for such pressures.

The bottom lining is reinforced with $\frac{3}{8}$-in. square corrugated bars, which have their ends hooked over the lowest reinforcing ring. Vertical $\frac{5}{8}$-in. square bars, spaced 3 ft. on centers, were used as vertical distributors. Each reinforcing ring is made up of six sections lapped 30 in. and wired. The rings were also wired to the vertical reinforcement at every intersection.

The forms consisted on the inside of vertical sheathing extending the full height of the reservoir, and of horizontal sheathing on the outside. The thickness of the bottom lining varies from 3 in. to 6 in., so arranged as to offer better drainage than was obtained in the old tank.

The reservoir was completed on October 12, 1911, and filled for the first time to its full depth on November 11, 1911. No leaks whatever have thus far appeared. The only precaution to render the reservoir water-tight other than that of using a fairly wet concrete, which was mixed in the proportion of one part of cement to two parts of sand and four parts of $\frac{3}{4}$-in. broken trap rock,

FIG. 1.
PLACING STEEL, SEPTEMBER 20, 1911. RESERVOIR AT SUFFERN, N. Y.

FIG. 2.
FINISHED RESERVOIR, NOVEMBER 11, 1911. ALL EXPOSED WORK NEW CONSTRUCTION.

was to wash the inside of the tank with a semi-liquid Portland cement.

An increase in the storage capacity of 294 000 gal. was obtained at a cost of $2 500, which was the contract price for this work. The location of the reservoir on a steep mountain slope about 180 ft. above the street level added considerable to the cost of hauling the structural material to the site, and, consequently, to the contract price.

SOME WATER SUPPLY PROBLEMS ENCOUNTERED IN THE SEMI-ARID REGIONS OF THE UNITED STATES.

BY CLARENCE GOLDSMITH, ASSISTANT ENGINEER, HIGH PRESSURE FIRE SERVICE, PUBLIC WORKS DEPARTMENT, BOSTON, MASS.

[*Read March 13, 1912.*]

After the serious troubles which the local members of the Association have undergone during the past six weeks, due to the exceptional depth to which the frost has penetrated, it may be somewhat of a consolation to them to have their minds refreshed by a brief enumeration of some of the difficulties along other lines which are encountered by their co-workers in the semi-arid regions of the United States.

The cities of Los Angeles, Cal., Butte, Mont., and Denver and Colorado Springs, both of Colorado, have been selected to illustrate the problems which present themselves to a water-works engineer in a locality where the yearly rainfall is small. The mean yearly rainfall at the above-mentioned cities is less than eighteen inches, while that in New England is slightly over forty-five inches; so it will be clearly seen that the difficulty of developing an adequate supply is much greater than on the North Atlantic coast. A second consideration of almost equal importance in providing an ample supply is the rapid growth of these Western cities, which requires the supply to be developed more rapidly and a larger margin of safety to be maintained than is necessary in the slower-growing Eastern cities.

The city of Los Angeles, supplied by a municipally owned plant, is located a few miles inland from the Pacific coast, and the built-up portion commences just south of the mouth of the San Fernando Valley, the watershed of which comprises 526 sq. miles. The average annual rainfall in the city is 15.93 in., and it increases on the northern slopes of the mountains about the valley to about 22 in. There is practically no precipitation during July and

August, and only 15 per cent. of the annual rainfall occurs in the six summer months. The rainfall is largely absorbed by the vast gravel and débris deposits which line the floor of the valley to a great depth, thus forming a large subterranean lake which appears as the Los Angeles River near the outlet of the valley. This perennial stream of great constancy has an average annual stream flow of from 29 000 000 to 35 000 000 gal. per day. The readings upon which the above figures are based are taken at the hours of greatest transpiration, for it is observed that the flow is some 2 000 000 gal. less when the vegetation is subject to the heat of midday. The total amount which can be derived from all sources of the supply for short periods of time is about 59 000 000 gal. per day.

The city has acquired the exclusive rights to all water, both surface and subsurface, of the entire watershed to the southern city limits. The upper valley was until recent years one of the most productive areas in the state of California, but the courts forbade any pumping of water for irrigation purposes within its confines, basing its decision on the fact that water required for municipal purposes produced the greatest good for the largest number of people. Thereupon agricultural activities practically ceased.

Water is withdrawn at seven points so distributed as to intercept the entire flow; four are within the valley, one at its mouth, and two within the city. Of the first four, the Main Supply diversion is located eight miles northwest of the city, where the stream flow is diverted by a low timber and gravel dam into a concrete conduit about five miles long, which leads to Silver Lake, a distributing reservoir. The greater portion of this conduit was only covered to the spring line until about two years ago, but it never showed any signs of expansion or contraction cracks, although exposed to the heat of the Southern California sun. The estimated minimum supply from this source is 13 000 000 gal. per day. The river disappears in the coarse gravel deposits immediately below the Main Supply diversion, and the subsurface flow is intercepted by six 10-in. wells from 160 to 239 ft. deep. Water ordinarily stands 5 ft. below the surface of the ground, and when the wells are being pumped by an air lift, at the rate of 4 000 000 gal.

per day, into the main supply conduit, during the summer months, the water plane is lowered 25 ft.

At the Crystal Springs diversion, one and a half miles below the Main Supply diversion, the river again appears on the surface and its flow is diverted by a low brush and gravel dam, at the rate of 12 000 000 gal. per day, into the Low Gravity conduit, which extends about five miles to Buena Vista reservoir, and has branches leading to Bellevue reservoir and to the main supply conduit. This supply is augmented by two lines of percolation pipes and an infiltration gallery which extends across the flood plain of the river, and in addition there are six 12-in. wells which can be pumped by air into the conduit line during periods of maximum consumption. The total available supply at this diversion is 23 000 000 gal. per day.

Three miles below this latter diversion there are five 12-in. wells which can furnish about 4 500 000 gal. per day. Ordinarily water stands 10 ft. below the surface, and when being raised by a centrifugal pump into the Low Gravity conduit the water plane is lowered 15 ft.

At the point where the river emerges from the valley, the latter is very narrow and a ledge extends across its bed, between the hills on either side, very near the surface, thus forming a submerged dam which maintains the water plane in the valley. Across these narrows a tunnel, 97 ft. below the bed of the river, extends through solid rock 2 100 ft., and from the surface of the ground are driven nine wells, with slotted casings 12 to 16 in. in diameter, through the ledge into the tunnel, thus intercepting all the underground flow from the valley. About 6 000 000 gal. can be pumped from this source during periods of maximum consumption. From two well fields in the city, containing eight 12-in. wells, 8 000 000 gal. can be raised and pumped into the distribution system when the other supplies are insufficient.

The above-mentioned source of supply was the only one that was available without the expenditure of a large sum, and any development of importance would require several years to render it available. Therefore, the Water Department was compelled to adopt strenuous means in 1905 to conserve the present supply until an ample one could be developed. The growth of the city has been

phenomenal. The population in 1900 was 102 479, and in 1910, 319 198, showing an increase of 211.5 per cent. in ten years, and a prospect of a like future growth seemed probable, but it necessarily depends upon ample water supply. In 1905, with a population of 225 000, the average daily consumption was 34 000 000 gal., or a per capita of 151 gal. with 8 800 meters in service, and in 1909, with a population of 300 000, 36 000 000 gal., or a per capita consumption of 120 gal. with 32 700 meters in service.

From the above it will be seen that the population increased 75 000, while the average daily consumption increased only 2 000 000 gal., and practically all the saving can be attributed to the judicious installation of meters and their proper maintenance. Here is a point which should not be slighted and which can be exemplified by this city perhaps better than by any other. The full benefits and best results of the meter cannot be attained without constant attention to their upkeep, and the compiling of accurate records in order to determine the types and makes best adapted to the particular service. The meter and service department is well organized and may well serve as a pattern to any city which is undertaking the general installation of meters.

The question of irrigation during the periods of maximum consumption is of primary importance, and much study has been given to this subject by the officials. One thing has been clearly demonstrated, and that is that the most luxuriant and healthy verdure is not grown on ground which receives the greatest amount of irrigation, but rather that which has received the least, provided it has been intelligently applied. Much depends upon the time of day at which the water is applied, but in general it is safe to say that for the dwelling-house lawn an application divided into two periods, one of thirty minutes in the early morning, and one of thirty minutes in the late evening, produces excellent results. It is to be hoped that more complete experiments can be conducted along these lines, and that the consumers may be educated so that they may be able to produce the maximum results with the minimum amounts of water applied. That this will probably come about within a few years seems certain, for the larger irrigation projects in the West are devoting much time to a study of this phase of the question.

In 1905 the citizens of the city, realizing keenly that the future of the city depended upon an adequate water supply, voted to proceed with a construction necessary to bring water from the Owens Valley to the city. The work entailed by this project is now well under way, and the city will probably enjoy the benefits of an ample supply in 1913. The intake of the Owens River is located 37 miles above Owens Lake, about 258 miles north of the city. The watershed tributary to the river has an area of 2 800 sq. miles, and contains twenty-four mountain peaks covered with perpetual snow, thus insuring an unfailing supply which will be at its maximum during the summer months when the largest amounts of water are used in the city. The water will be brought from the intake at elevation 3 812, through 226 miles of conduit, siphons, flumes, and tunnels, $7\frac{1}{2}$ miles of reservoir, and $12\frac{1}{2}$ miles of natural watercourse, to the San Fernando storage reservoirs, elevation 1 130, which will be constructed 18 miles northwest of the city at the head of the San Fernando Valley. The carrying capacity of the conduit will be 280 000 000 gal. daily, and five equalizing storage reservoirs will be located along the route to insure the continuity of the supply, and several power stations will be erected along the route of the conduit to take advantage of the rapid drops in elevation which occur at several places. At the time of the inception of this project it was one of the largest in reference to the distances involved which had ever been undertaken, and when one recalls the relatively small size of the city, all credit should be given to the engineers and the citizens for attempting the consummation of such a project, which involved such an enormous expenditure.

It may be well to stop here and consider the activities of the water department for the period of the previous seven years. The construction of the new supply works has been pushed as rapidly as circumstances would permit; at times over six thousand men have been employed. The per capita consumption has been reduced by a careful maintenance of the distribution system and the installation of about six thousand meters per annum, and the works within the city have been extended by the laying of about thirty-five miles of main pipe and the installation of 4 100 services each year, all of which has been accomplished with a comparatively

small force due to the team work of the employees, which is facilitated by the excellent organization.

The city of Butte, Mont., having a population of about 40 000, lies three miles west of the Continental Divide, and the elevations within the city range from 5 425 to 5 900. Owing to its location at such an elevation there are no large watersheds that are available to furnish an adequate gravity supply. The mean annual rainfall is 15.17 in., with an occasional minimum of 10.29 in. This city has not had an exceptionally rapid growth of population, having increased only 30 per cent. since 1900, but is of special interest from the viewpoint of supply, due to its peculiar location.

The Butte Water Company, operating under a perpetual franchise, furnishes entire supply from five watersheds, sparsely to densely wooded, and uninhabited, which will be briefly described. Basin Creek, which lies south of the city, contains two storage reservoirs, one of which, formed by a masonry dam 250 ft. long and 60 ft. high, at elevation 5 860, has a capacity of 189 000 000 gal.; and the other, about $1\frac{1}{4}$ miles further up the creek, formed by a timber-crib earth-filled dam, 330 ft. long and 40 ft. high, with a concrete core wall, has a capacity of 64 000 000 gal., at elevation 6 199. The run-off of the watershed is supplemented by the headwaters of Fish Creek, which is intercepted and brought across the Divide in a wooden flume about 7 miles long. This supply feeds the low service through a supply main about 12 miles in length, three fourths of which is 24-in. wood stave pipe, the remainder being 20-in. kalameined pipe. The line will carry about 6 000 000 gal. per day.

A condition which was observed on this watershed may be of interest. The bottom of the lower reservoir was carefully stripped before it was filled, and the surface consists of fine clean quartz sand, while no work was done on the upper reservoir, and the original leaf mold and stumps were covered when it was flowed. In the upper reservoir there is practically no trace of algæ growth, while in the lower reservoir, with its clean bottom, this growth becomes extremely troublesome during certain seasons of the year.

The second and more important source of supply is that of the Big Hole River, which drains a watershed on the eastern slope of

the Rocky Mountains, extending southwest to the Bitter Root Mountains. The maximum observed stream flow is 90 000 000 gal. At a pumping station located 25 miles southwest of the city the water is raised from the river at elevation 6 393, against a head of 850 ft., to a masonry standpipe through a riveted steel pipe. The two Nordberg pumps are of very heavy construction to work against this high head; the plungers are $11\frac{1}{4}$ in. in diameter and the rods and tail rods are 7 in. in diameter. From the standpipe the water flows by gravity about 8 miles to the South Fork Reservoir, which is located in the South Fork of Divide Creek, about 18 miles southwest of the city, and formed by an earthen dam with a concrete core wall. The capacity is 13 500 000 gal. The run-off of the watershed above the reservoir contributes to this supply on an average about 1 000 000 gal. per day. Water from this reservoir flows by gravity to a distributing reservoir within the city, at elevation 5 960, which supplies an intermediate service. The supply line, 18.5 miles long, is of particular interest owing to the method of its construction, which enables wood-stave pipe to be used in a large portion of the line, which only for special features would be under an excessive head. These devices consist of four concrete regulating chambers, each divided into two sections by a concrete weir. In the lower of these sections a float is placed which controls a valve on the pipe entering the upper section, so that when it is desired to curtail the supply coming to the reservoir within the city, a gate is closed immediately outside the embankment, and the water backs up successively in the four regulating chambers, each of which throttles the supply entering it without producing any greater head on the individual sections of the wood stave line than is due to the difference in elevations of the successive weirs.

The fifth source of supply consists of two impounding reservoirs in Yankee Doodle Creek, about $7\frac{1}{2}$ miles northwest of the city, and at the present time it is estimated that this supply can furnish about 3 000 000 gal. per day. The distribution system within the city is very difficult to maintain, as the mines have been excavated under a great portion of it, and the timber bracing is continually settling. Kalameined pipe, a patented article of wrought iron or steel, with a special metallic coating, joined by sleeves with

lead joints, is used exclusively, as failures are portended by small leaks rather than by sudden ruptures, as would be the case with cast-iron pipe. As an example of the rapid settlement which has taken place, a 6-in. line laid in a tunnel may be cited. This line is connected through elbows at either end, and about once a year 2 ft. of pipe has to be cut out of the line.

The city of Denver is located on either side of the South Platte River, about 15 miles from the eastern foothills of the Rocky Mountains. Its surface is generally undulating, ranging from elevation 5 134 to 5 482. The population in 1900 was 133 859, and in 1910, 213 381, showing a gain of 59.4 per cent. in the last ten years. The mean yearly rainfall averages about 14 in., with a minimum of about 8.5 in., about 64 per cent. of which occurs between April and August. The yearly evaporation is about 69 in., — practically double that which obtains in Boston. The works which supply the city are owned by the Denver Union Water Company, which owns and controls practically all the water rights which are available for furnishing domestic supply to the city.

The South Platte River furnishes the supply from its surface and subsurface flow at two points outside and one within the city. The flow from a small creek is diverted into a distributing reservoir by infiltration, and that from Bear Creek is stored in one of the storage reservoirs. The river above the city drains an area of 3 910 sq. miles, three fourths of which is of granitic formation and generally sparsely wooded and mountainous, and the remainder prairie land below the foothills.

The precipitation in the mountains is mostly snow which accumulates in the winter months and melts during the months of May and June, producing a high-water period of less than two months' duration, while the low-water period extends over the remainder of the year, during which period the stream flow frequently falls below 20 000 000 gal. per day.

The prairie land when irrigated is extremely productive, so it is not surprising that the stream flow is over-appropriated by the ranch owners and the water company.

The only means to enable a greater amount to be available was to construct a storage reservoir in the watershed; therefore, the

Cheesman reservoir was completed in 1904 on the south fork of the South Platte River, 50 miles south of the city. This storage reservoir is formed by a massive stone masonry dam in a narrow gorge. It is 708 ft. long, 176 ft. thick at the bottom, and 18 ft. thick at the top, and has a maximum height from the stream bed to the top of the dam of 236 ft., a capacity of 25 760 000 000 gal., and an area of 874 acres, at elevation 6 836. The construction of the dam required 80 000 barrels of cement, which was hauled by teams of sixes a distance of 23 miles over a mountain road, and the stone, a gray granite, was quarried within one-half mile of the dam site. The stones are of a uniform thickness of 2 ft., and the mortar joint is 1 in. thick. The masonry work was so well executed that when water is flowing over the spillway, which is located 200 ft. north of the dam in a depression between two mountains, there is no trace of leakage or even sweating on the downstream face of the dam. Water is withdrawn through tunnels driven through the granite mountain north of the dam. Three tunnel entrances at different elevations are controlled by hydraulically operated valves, access to which is provided through man-way tunnels. During the irrigation season, in addition to the water withdrawn for the domestic supply, as much water as is entering in the streams at the upper end of the reservoir must be returned to the river below the dam to take care of the irrigation rights.

This water is carried in the stream bed for about 30 miles, where that portion used for domestic supply is diverted at the Platte Cañon head works into either the Platte Cañon reservoir, or to Marston Lake, through a conduit line. Platte Cañon reservoir is about two miles below the head works, and forms a sedimentation basin of 300 000 000 gal. capacity from which water is passed through slow sand filters having an area of $10\frac{1}{2}$ acres, with a daily capacity of 35 000 000 gal. Water may also be applied to these beds from two small settling basins which are fed directly from the stream.

The supply lines of the system are of exceptional interest. All are continuous wood-stave pipe, are well cross-connected, and the flow through each is recorded by a Venturi meter. The oldest of the longer lines was installed in 1890, and has a length of about 18 miles, in which length there is 44 ft. fall, and the line shows a

carrying capacity, by meter measurement, of 8 000 000 gal. per day. There are three other lines of similar length, a 30- and 34-in. line having a capacity of 13 000 000 gal., a 40-in. line having a capacity of 23 000 000 gal., and a 44- and 48-in. line having a capacity of 25 000 000 gal. The continuous wood stave pipe has proved itself well adapted for conduit lines, as the cost of installation is much less than that of steel or of cast iron, not only due to the lower cost of the material, but also to the greater ease with which it can be transported, particularly to points difficult of access. The maintenance is moderate, and in case of failure, repairs can be made much more expeditiously than either on steel or cast iron; and another reason of almost equal importance is that the coefficient of its carrying capacity remains constant. In applying the Hazen-Williams formula one is perfectly safe in using a coefficient of 125 in making calculations, and there are several lines which show coefficients as high as 140. In different parts of the West various woods are used to make the staves — redwood, Oregon fir, and Texas long-leaf pine. The redwood is somewhat too soft to take the tension of the bands without allowing them to cut in too deeply, but the two latter-named woods have proved very satisfactory, and practically all of the Denver lines are made of Oregon fir pine. The wood in the line when properly installed, that is, when all points are below the hydraulic gradient, and suitable air valves are provided on its summits, has a very long life, but the bands, which are the first to fail, have a life of only about twenty-five years, depending upon the quality of the original material, their coating, the care with which they were installed, and the nature of the soil. Experience shows that a rolled thread is preferable to a machine-cut thread, and when they are used it is unnecessary to upset the thread end of the rods in order to secure their full strength.

The remaining supplies do not present any features particularly worthy of note, both being infiltration galleries, one of which delivers by gravity and the other by pumps. All water is filtered, either naturally by infiltration or artificially by either slow sand or mechanical filters, before it enters the distribution system.

The average daily consumption in 1910 was 49 200 000 gal., which, with an estimated population of 213 000, gives a

per capita consumption of 229 gal., and the maximum daily consumption is about 70 000 000 gal. No particular effort has been made to reduce the consumption, and there are only about 400 meters in service. Upon first thought it would not appear to be an economic operation of the works to foster so large a consumption, as it has required the installation and maintenance of numerous large conduit lines, but if this water were not used for domestic supply the present water rights would be lost, and it would be well-nigh impossible to secure additional rights which would be required as the city grows. Now any large increase in population can be easily served by adopting measures to reduce the per capita consumption.

The position of the Denver Union Water Company is unique, for although it has been in litigation with the city since the expiration of its franchise in 1910, and prior to that time had many disagreements with the city, it continues to develop the works and expends more than half a million dollars each year, and it always has maintained a system, the efficiency of which is equalled by few cities whose works are either privately or municipally owned.

Colorado Springs is located about 75 miles south of Denver, and has a population of about 30 000. The city lies at practically the same elevation as Denver, and enjoys the same climatic conditions. The supply is derived from a series of watersheds which comprise the southeastern slope of Pike's Peak. Their combined area is 29.57 sq. miles, and that which does not lie above the timber line is from moderately to sparsely wooded. The rainfall on the watersheds varies from about 15 to 30 in., and the snowfall from 97 to about 200 in., but the run-off from the latter is very uncertain, for at these high altitudes it is not uncommon for practically all the snow to disappear without contributing more than a very small amount to the run-off. There are six storage reservoirs which have a combined capacity of 2 194 000 000 gal. Two of these are above timber line, and the higher, at elevation 12 099, is the highest storage reservoir in the world. From the lower storage reservoir water is discharged into Ruxton Creek, and at a point $1\frac{1}{2}$ miles below is diverted into a 16-in. main by a low timber-crib dam at an elevation of 9 241. This line extends for about one-half mile

to a reinforced concrete equalizing reservoir from which a 20-in. riveted steel pipe, having a capacity of 17 000 000 gal. per day, follows the contour of the mountains in a gradually descending grade for the first part of its course, and then abruptly descends to a power house located in Manitou, where an available head of 2 400 ft. is used to operate Pelton wheels which discharge into a settling basin, from which point three lines, an 8-in., 16-in., and 24-in., convey water into the distributing reservoirs in the city. The average daily consumption in 1910 was about 8 000 000 gal., which shows a per capita consumption of 232 gal. The maximum occurs during the summer months, and 13 000 000 gal. was used in July, 1910.

DISCUSSION.

THE PRESIDENT. Mr. Goldsmith, I was interested in what you said about the two reservoirs at Butte, Mont., one of which had been stripped and the other not, and one containing bad water and the other good water; have you any theory upon which to explain that?

MR. GOLDSMITH. No, I have not, and the superintendent of the works says that it is beyond him. He was building a reservoir on Yankee Doodle Creek when I was there, and he was taking no chances but was stripping the site. I saw the water myself, and in the upper reservoir it was as clear as could be, while in the lower reservoir, which has this fine quartz bottom, it was simply green with algæ. Mr. Carroll is probably one of the most able water-works superintendents in the country. He is an Annapolis man, a thorough-going engineer in every respect, but he has been unable to solve the problem.

THE PRESIDENT. Do I understand that the water is drawn from the upper reservoir to the lower?

MR. GOLDSMITH. It flows down a brook for about three quarters of a mile.

MR. RICHARD A. HALE.* I would like to inquire if the life of the wood pipe and the bands, etc., does not depend on the material in which the pipe is imbedded? The

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reason I ask is that I have recently taken out in Lawrence a wooden penstock which has been in for forty-six years. It was composed of white pine, surrounded by iron bands. The material in which it lay is not clay puddle, but ordinary material, something like river silt, possibly, puddled. There is no indication whatever of decay in the wood, and a section across the iron bands shows them to be as bright as they were on the day on which they were put in. There is apparently no reduction whatever in the section, and every part, the wood and iron, seems to be exceedingly well preserved. There was, of course, no exposure to the air, and I was wondering whether the life of this kind of pipe mentioned by Mr. Goldsmith did not depend very much on the material in which the pipe is laid and upon whether or not it is exposed to air and water and is alternately wet and dry.

MR. GOLDSMITH. I believe I covered that point. I said that among other things the life of the pipe depends upon the material, the soil, in which it is laid. I would say that the failure of the bands on wood stave pipe up to the present time has practically always been in the threads, and the rolled thread had not been used long enough to have it determined where the failure is hereafter going to be. A few staves in a line would go bad, and when they took those portions out and moved the nuts on the bands, they found that the thread was practically all gone.

Another thing that has been developed by the Denver Union Water Company has been in connection with the putting on of the new bands. They used to be made in a complete circle, and in wiggling them under the pipe a little of the coating would be torn off. Now they are making the bands in two sections, held together by a malleable iron clamp or saddle. That method of construction not only enables them to get the bands around the pipe without injuring the coating, but also to get a great deal better tension on the pipe. They like to lay the pipe in the winter, for the staves are dry, and when there is a little frost on them they drive home better than they do in warmer weather.

THE PRESIDENT. Have you any theory or any reason upon which you can explain why the rate per capita at Los Angeles should be so high?

MR. GOLDSMITH. It is on account of the rainfall. Only 15

per cent. of the rainfall, the total amount of which is very small anyway, is during the summer months, and there is practically none during July and August. Now Los Angeles is a garden city, you may say. When I was looking up the question of irrigation I found two estates, each of which occupied half a block. The meter on one estate showed that during the year they had used water enough, including what was used for household purposes, the exact amount of which of course could not be determined, to have covered the land to a depth of 14 ft., and, in the case of the other estate, to have covered it to a depth of 7 ft. It is a city of homes. Practically every one owns a little home and has a little garden, and nothing will grow in it without irrigation. That probably accounts for the high rate.

MR. G. C. WHIPPLE (*by letter*). The writer has been very much interested in reading Mr. Goldsmith's paper, and especially that part of it relating to the growth of algæ in the reservoirs of the Butte Water Company. The fact that algæ have given trouble in the reservoir that was carefully stripped before it was filled, and have not given trouble in the upper reservoir, which was not stripped, is in line with numerous instances which have come to his attention during recent years. It is quite evident that our ideas in regard to the control of algæ growths in reservoirs must be modified by these recent observations, and stripping cannot any longer be regarded as a general panacea for this trouble. It is evident that there are many conditions other than that of providing a supply of organic food material that are involved in the problem. Therefore, if the author could give us further information in regard to the nature of the algal growths and the physical and topographical conditions of the reservoirs, he would be adding to the knowledge that must be accumulated before an adequate theory as to the cause and control of algæ growths can be advanced.

Since the early work on the subject of algæ growths was undertaken by members of this Association twenty years and more ago, comparatively few investigations in this country have been published and the science of limnology has been allowed to wane. Meantime, however, some extensive investigations have been made in Europe, especially in Scotland, where questions of temperature, currents, etc., have been investigated in detail. References to this

foreign literature may be found in the files of the *Internationale Revue der Gesamten Hydrobiologie und Hydrographie*, which has been published since May, 1908. In this country the most important references to the subject are the report of Messrs. Allen Hazen and George W. Fuller on " The Relation of Reservoir Stripping to the Improvement in Quality of Water, " published in the Annual Report of the Board of Water Supply, City of New York, 1907, and the monograph of Dr. Edward A. Birge and Chancey A. Juday on " The Dissolved Gases of the Water and their Biological Significance," published in Bulletin XXII of the Wisconsin Geological and Natural History Survey.

The writer hopes to review all of this literature during the near future, and thus make it available to the members of the Association, hoping that it will stimulate anew the interest in the general subject of limnology.

METHODS OF THAWING FROZEN SERVICE PIPES, AND DISTRIBUTING THE COST THEREOF.

TOPICAL DISCUSSION.

[*March 13, 1912.*]

MR. J. J. PRINDIVILLE.* Mr. President, there is one question I would like to bring up here this afternoon which is of vital interest to the smaller departments, and that is, how to treat the services entering from the street mains to the houses of the consumers.

This last winter, which has probably been as cold as any winter in the past twenty-five years, we have had a great deal of difficulty from freezing. There has been very little trouble with the mains, but there have been from 150 to 200 services frozen on private grounds. Those services are paid for, when they are put in, by the owners, and when they are frozen the owners call on the department to thaw them out. Now the question is as to whether the expense of doing that should not be borne by the owners rather than by the department. The reply to that is that the services were put in, in almost every case, under the direction of the department, and the owners say that under those circumstances, as the department assumed the responsibility for putting them in, it should pay for the expense of thawing them out. This becomes quite a serious question when we have a winter like the past one, and so I would like to bring the matter up for discussion to see if we cannot get some information as to the best way to treat the subject and learn the opinions of the members as to whether the department or the owners of the services should pay the charge for thawing them out. Another question is as to the best method in use for thawing out these service pipes.

THE PRESIDENT. I would say that we have had a great many frozen services in Worcester this year, and they were laid by the Water Department. We have taken the attitude that where a

* Member and Secretary Water Commissioners, Framingham, Mass.

service was frozen in the street the city would assume the responsibility, but if the freezing clearly started in the cellar we would charge the expense of thawing to the consumer. That seems to be perfectly fair.

MR. PRINDIVILLE. What would you do if the house was 100 ft. from the street and the service was frozen under the lawn?

THE PRESIDENT. I should hold the consumer responsible, if the freezing was on his premises. Oftentimes services are put in when the grade of the lawn has not been established, and in those cases the Water Department uses the best information it has, and if it turns out that the owners do not fill in as much as they had planned to do, so that the frost gets down and the pipe freezes, we do not think the department should be held responsible. But if the grade is established, and the department puts the service in, we think we are morally bound to take care of it, unless the freezing begins in the cellar and works out through the cellar wall. Then we think that the consumer should pay for thawing the pipe out.

MR. EDWIN C. BROOKS.* I would like to ask how you determine that it starts in the cellar and works out.

THE PRESIDENT. It isn't difficult to determine that in a good many cases. Sometimes when we start thawing we will get the water through before we have gone more than two or three feet beyond the wall.

MR. BROOKS. The stand that we have taken in Cambridge has been that we were to furnish water to the sidewalk cock, and that the owner is responsible for what happens from the sidewalk cock to the house. I wish some of you gentlemen who have put on goosenecks and some of those contraptions that are supposed to take up the expansion and contraction of service pipes had to wiggle the thawing coil around through some of them. I think it would convince you that, although they might have advantages, they certainly add to our difficulties. And, another thing. Why can't there be some uniform method of putting services into houses? Why can't they come in above the cellar bottom, and not go into a little well, as they often do, and then run back under the concrete floor of the cellar? It is very difficult to get a coil into the pipe

* Superintendent of Water Works, Cambridge, Mass.

under such conditions. It seems to me that before we live a great many years longer we ought to adopt some uniform method of putting in supplies which will provide that the supply shall enter the cellar two or three inches or more above the finished cellar bottom, and that the stop and waste valve shall be accessible. It would add very much to the ease of thawing out supplies if something of that sort could be adopted. Then there is another thing: to have ample water-ways in sidewalk cocks and in corporation cocks adds very much to the peace of mind of the person who is trying to get a coil through, instead of having one of these little oblong openings which the coil will scarcely go through. There are a good many of these little details which, if they were attended to, would add very much to our ease in getting along, and if we are to have many winters like the past one, it would seem as though they would have to be provided for.

Mr. Frank A. McInnes.* With approximately 100 000 services in Boston, we have had about 200 frozen. I have a list of deposit slips, and have to settle whether we shall pay the money back or keep it. In the majority of the cases it is the same old problem as to where the freezing started, — whether on the premises or in the street.

With regard to the method of thawing the pipes out, I am satisfied that there is one best way, and that is to have your own electric plant, consisting of motor and generator of say 25-kilowatt capacity, which you can put on an electric truck or on a wagon and move from place to place. We have lost a large amount of time both with the A.C. and D.C. current in getting connections, grounds, etc., and have decided that we must have our own outfit. I have talked with some of the water-works supply men and have asked them to get up something and put it on the market before next winter.

The next best thing to electricity is steam under pressure, live steam carried right from the boiler into the pipe.

Mr. Brooks. I would suggest a small portable tubular boiler operated by either gasolene or kerosene under pressure to boil the water that you use in your coils, so that when you start thawing out you will be sure to have plenty of hot water. In many of

* Division Engineer, Sewer and Water Division, Boston, Mass.

the poorer districts, when the supplies are frozen, a man will have to go from house to house to get a pail of hot water. There are but few hot water boilers in the vicinity. He may find a teakettle of water on the stove, but the woman will want it herself, and then the man will have to run to the nearest engine house or schoolhouse or some place of that kind with the hope of getting some water there. It is much more satisfactory to have a small boiler from which you can put a steam jet into your pail and keep the water boiling hot, so it can be used in the coil when it is hot instead of lukewarm.

There is another idea that I have had in mind, and that is whether it is not possible for us to use the spiral steel pipe that is rolled in a spiral and locked together. They use it for tube blowers, and I understand it is made in sizes as small as $\frac{3}{8}$ in. It seems to me that would stand rough usage and not be liable to be pulled apart in pulling it out of the services, and would be very much better than the ordinary block tin coil that we are using now.

Mr. McInnes. In Boston we use small boilers delivering live steam under 4 or 5 lb. pressure through a $\frac{3}{8}$-in. lead pipe into a service or through a $\frac{5}{8}$-in. pipe into a larger pipe.

Mr. Prindiville. The question which troubles me still remains, Mr. President, and that is, who is to pay? In most departments the rules provide that the services must be put in subject to the approval of the department, — either put in by the department or subject to the approval of the department. Now if they freeze, how are you going to decide, as has been said, whether the freezing begins at the street end or at the house end? The pipes are frozen and the owners come to you for relief. At one time this winter we had so many of such cases that it took us two weeks to get around. In a number of instances there was severe sickness in the houses, and it was a very great hardship not to be able to use the waterclosets and bath-rooms.

Now suppose you say to the owner that he has got to pay to have his service thawed out and that you will require a deposit. The owner refuses to pay, on the ground that you have got to furnish him with water. You are already charging him for it, and you have got to furnish it to him, he claims, and you are not giving it

to him. It seems to me that there is quite a big question for us to consider. It may be a legal question as to whether you can take the ground that you will not thaw the service out and yet will charge the owner for water. In order to get some light on this subject, and the matter is one which is of particular importance to small departments, I would suggest that a committee of three or five, whichever number you see fit, be appointed to take this matter up and make a study of it and recommend to the Association the best method to adopt as to who must pay the bills for thawing frozen services. It does not seem right, in one aspect of it, for us to stand by and say we will not thaw them out, and yet at the same time charge a minimum rate for the water.

THE PRESIDENT. Our way in Worcester would be to thaw out the service and then to thresh out afterwards the question of who shall pay for it. Get the water running in the first place, for you will then be on the safe side, and take up the question of payment later. I think it would be very difficult to establish any uniform practice for the different cities and towns. It seems to me the question would be very largely a local one.

MR. PRINDIVILLE. If you eliminate the charge in one case, you have got to do it in all cases.

THE PRESIDENT. Under the same conditions, yes. You have got to be consistent. I have learned that you cannot safely make any exceptions.

MR. FRANK C. KIMBALL.* To answer the gentlemen's question specifically, it seems to me that it must depend entirely upon the conditions under which service pipes are laid in the particular place. Some departments assume the laying of the pipes to the cellar wall, charging a certain price per foot, the cost, or whatever it may be, and laying them as they see fit, using the kind of pipe they may choose and at such depth as in their opinion is necessary. I think in such a case as that there is hardly any question but what the expense of thawing the pipe should be borne by the department. On the other hand, some departments run merely to the curb or to the street line, and it is for the owner to get a plumber and bring the water into the house. Even though that be done subject to the approval of the department, I think in such a case it would

* General Manager, Commonwealth Water and Light Company, Summit, N. J

be for the householder to pay the expense of thawing out the pipe, because, while it is subject to the department's approval, it is not beyond the province of the property owner or his plumber to do a better job than the department requires, although they seldom do it. So, as I say, in all cases I think it is the way the rules or regulations of the department read which will largely govern as to whether the department or the property owner pays the bill. As to drawing an exact line where the freezing begins, whether in the cellar or at the main or at the property line, you cannot always do it.

MR. WALTER H. RICHARDS.* Mr. President, I agree with Mr. Kimball. I think if the city lays the pipe across a man's lawn into his house, the city should be at the expense of thawing it out in case it freezes, for the city assumes responsibility by laying it.

To determine just where the freezing starts is very difficult. I think it is a very rare case in which you can do it with absolute certainty. I have one case in mind where the pipe froze solid right out to the curbstone and the service did not freeze at all, although it was not laid any deeper than the pipe to the sidewalk was.

MR. ARTHUR F. BALLOU.† We began by using live steam for thawing pipes. The city of Woonsocket is responsible for the pipe to the curb line.

We investigate each case of freezing that is reported to us. If we get water at the curb we at once shut it off so as to drain the private part of the pipe and prevent the freezing from working back into our part of the pipe. If the service is off a big main, one of the principal arteries of the city, we put in steam and thaw out the ground so as to protect the main pipe.

The requests to be thawed out became so numerous that we had to begin to use electricity because we could do the work so much quicker. We thawed the consumer's part of the pipe and ours at the same time, and we bore the expense, if both parts of the pipe were frozen. But where we had water at the curb we notified the consumer that we should expect him to pay us the cost,

* Engineer and Superintendent, Water and Sewer Department, New London, Conn.
† Superintendent of Water Works, Woonsocket, R. I.

and nobody demurred at that. They seemed to expect to pay it.

We have had quite a lot of trouble this past winter. We had over one hundred frozen services, and everybody realized that we were working hard to remedy the conditions, but that we were up against a pretty tough proposition. Perhaps that had something to do with the attitude of the consumers. They treated us very kindly, perhaps differently than they would have if there had only been five or six cases. There was only one man who was dissatisfied, so far as I know, and he had only been taking water about four weeks. He is wiser now, and I think if he had had the water for several years he would have realized the conditions better. Nobody demurred against paying the expense, and of course there were so many pipes frozen that the charges when they are divided are not going to be exorbitant. We did our best to protect our mains and to keep the consumers supplied with water.

I think in Woonsocket we look at the question of the service pipes a little differently from any man who has spoken here to-day. Anybody who applies for permission to make connection with our mains and to take water is given the privilege of making the connection. It is a privilege. We do not guarantee to give uninterrupted service; we cannot do that; and our consumers all take the water under those conditions. We do our best, of course, to keep the water flowing in the mains, but as far as any liability on the part of the city is concerned, we do not admit it. As a general thing, the people accept the service in that spirit. We have been very fortunate, we have not had many interruptions, and nobody ever attempts to be disagreeable. In case a main breaks they realize that we get to work and fix it as soon as possible, and they are perfectly willing to wait, and, of course, they are more so if they have a neighbor on another street who has water.

MR. MCINNES. One way to avoid trouble would be to adopt the method used by the largest city in the country, New York, and that is to have absolutely no responsibility beyond the main. That is the rule in New York City; they have charge of the main pipe and everything else is up to the owner.

MR. BROOKS. I think, Mr. President, that considerable

trouble might be avoided if services were not laid under walks leading up to the houses. It is frequently the case that a service pipe runs under the walk, which is kept shoveled off in the winter time, and, of course, the frost then has a chance to go down much deeper than it does on the lawn, which is covered with snow and where there is a coating of grass.

MR. FRANK L. FULLER. Mr. President, I would like to inquire what the cost of thawing out service pipes by an electric current is?

MR. MCINNES. I can tell you exactly what it cost us this year, but as it was all emergency work the data is really of little value. A great deal of time was lost trying to make connections, in running secondary wires and in waiting; we were actually working but a small part of the time. The entire cost of thawing divided by the actual number of services thawed, including one elevator pipe which took a half a day, amounted closely to $19. The total cost divided by the total number of services we thawed and tried to thaw, loosing a great deal of time on some without actual work, amounted to $14 apiece. With your own outfit, the expense is only a matter of a dollar or two at the outside.

MR. BROOKS. What do you use for power?

MR. MCINNES. With the A. C. current we used a 50-kilowatt transformer and a water rheostat working often without a ground. We got our primary on one side connected and let the ground take care of itself. I want to emphasize the fact that our cost of thawing is absolutely no criterion of what it should cost, because it was emergency work and we let nobody wait.

MR. FRANK E. WINSOR.* I do not think that I am qualified to speak on this matter, but as Mr. Fuller has asked the question as to the cost, I might say that in White Plains, N. Y., the Westchester Lighting Company has made a business of thawing out frozen services, of which there have been a great many during the past winter. The rule in force by the water department places the responsibility for the house service entirely upon the householder, and the department has no interest in thawing out service pipes. If such pipes freeze, the householder or owner of the property must arrange for thawing them out. The charge for thawing, where there are no particular complications, was fixed

* Department Engineer, Board of Water Supply, City of New York.

in the early part of the season as $7.50 and was later increased to $10 per service. In Tarrytown, N. Y., the same company has charged $15 per service during the past winter. Special prices have been made for large jobs.

MR. MCINNES. The owner of the outfit which was working for us told me that in the adjoining town of Norwood he thawed twelve services at once, so the expense would naturally be a good deal less than our cost. What we paid is no criterion, for our frozen pipes were isolated, in all parts of the city.

PROCEEDINGS.

March Meeting.

Hotel Brunswick,
Boston, Mass., March 13, 1912.

President George W. Batchelder in the chair.
The following members and guests were present:

Honorary Member.

Desmond FitzGerald.— 1.

Members.

S. A. Agnew, J. M. Anderson, C. H. Baldwin, A. F. Ballou, L. M. Bancroft, F. A. Barbour, G. W. Batchelder, F. D. Berry, A. E. Blackmer, E. C. Brooks, G. A. Carpenter, E. J. Chadbourne, J. C. Chase, J. H. Child, M. F. Collins, John Doyle, E. R. Dyer, E. D. Eldridge, J. W. Ellis, G. T. Evans, A. N. French, F. L. Fuller, M. L. Fuller, A. S. Glover, Clarence Goldsmith, F. H. Gunther, R. A. Hale, F. E. Hall, M. F. Hicks, H. C. Ives, W. S. Johnson, Willard Kent, F. C. Kimball, G. A. Stacy, Morris Knowles, C. F. Knowlton, F. A. McInnes, N. A. McMillen, A. E. Martin, John Mayo, F. E. Merrill, H. A. Miller, William Naylor, F. L. Northrop, T. A. Peirce, J. J. Prindiville, W. H. Richards, L. C. Robinson, A. L. Sawyer, C. W. Saxe, G. A. Stacy, W. F. Sullivan, J. L. Tighe, E. J. Titcomb, W. H. Vaughn, R. S. Weston, Elbert Wheeler, William Wheeler, F. I. Winslow, G. E. Winslow, F. E. Winsor, H. V. Macksey, T. G. Hazard, Jr. — 63.

Associates.

Builders Iron Foundry, by F. M. Connet; Darling Pump and Manufacturing Company (Limited), by H. H. Davis; Glauber Brass Manufacturing Company, by S. S. Freeman; Goulds Manufacturing Company, by R. E. Hall; Hersey Manufacturing Company, by Albert S. Glover and W. A. Hersey; Lead Lined Iron Pipe Company, by T. E. Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould; H. Mueller Manufacturing Company, by G. A. Caldwell; National Meter Company, by C. H. Baldwin and J. G. Lufkin; Neptune Meter Company, by H. H. Kinsey and R. D. Wertz; Norwood Engineering Company, by C. E. Childs; Pratt & Cady Co., by C. E. Pratt and M. J. Kane; Platt Iron Works Company, by F. H. Hayes; Rens-

selaer Valve Company, by F. S. Bates and C. L. Brown; A. P. Smith Manufacturing Company, by F. L. Northrop; Thomson Meter Company, by E. M. Shedd; Union Water Meter Company, by F. E. Hall; Water Works Equipment Company, by W. H. Van Winkle; Henry R. Worthington, by Samuel Harrison. — 24.

GUESTS.

I. P. Wood, inspector, Marlboro, Mass.; Henry C. Page, Arthur E. Tucker, Worcester, Mass.; Robert E. Whittle, Arlington, Mass.; John E. Minos, J. E. Parker, E. F. Hughes, Boston, Mass.; Ivers M. Low, superintendent water works, Weymouth, Mass.; Herbert W. Hunt, Reading, Mass.; Howard V. Allen, water commissioner, East Greenwich, R. I.; D. R. Howard, Woonsocket, R. I.; George E. Stimson, Rochdale, Mass.; W. F. Woodburn, Philadelphia, Pa.; John A. Thompson, A. E. Barrett, Lowell, Mass.; Frank S. Newell, John F. Browning, and John J. Mack, water commissioners, Salem, Mass. — 18.

The records of the last meeting were read by the Secretary and approved.

The Secretary announced that the Executive Committee had this forenoon voted to hold the next annual convention at Washington, D. C., during the third week in September.

Applications for active membership, properly endorsed and recommended by the Executive Committee, were presented from Charles E. Perry, Canajoharie, N. Y., engaged in sewer and water-works construction and design; Philander Betts, Newark, N. J., chief engineer Public Utilities Commission, State of New Jersey; and for associate membership from Francis H. Coffin & Co., Scranton, Pa., general sales agents for hydraulic supplies, particularly machine-made wood stave water pipe.

On motion of Mr. Thomas A. Pierce, the Secretary was directed to cast the ballot of the Association in favor of the applicants, and he having done so, they were declared duly elected members of the Association.

Mr. Frank C. Kimball, civil and hydraulic engineer, Boston, Mass., read a paper entitled "How the Water Emergency at Worcester, Mass., was Handled in the Summer of 1911, together with a Brief Description of Worcester's Sources of Water Supply." The paper was illustrated by stereopticon views. The President, Mr. Batchelder, spoke briefly upon the subject of the paper.

Mr. F. A. McInnes, for the Committee on Standard Form of Specifications for Cast-Iron Water Pipes and Special Castings, which was requested at the last meeting to consider and report as to the advisability of making some changes in the standard specifications, presented the following report:

Mr. President, — I am sorry that the chairman of our committee is not here, but I have the results of our labors and with your permission I will read the report:

MARCH 13, 1912.

NEW ENGLAND WATER WORKS ASSOCIATION:

In 1902 this Association adopted a Standard Form of Specifications for Cast-Iron Water Pipe and Special Castings which has been used during the past ten years by members of the Association and other users of cast-iron pipe throughout the country; in the meantime the American Society for Testing Materials and the American Water Works Association have each adopted standard specifications differing slightly from those of this Association.

While our specifications have well served their purpose, your committee believe that the time has come when certain changes should be made if they are to continue, economically, to make for the best results, and it therefore recommends that they be revised. Your committee realize from past experience that the questions to be considered will undoubtedly entail a large amount of work, involving the making of computations and drawings; it is, therefore, suggested that the matter be placed in the hands of a new committee of five, to be appointed by the President, and that the committee be authorized to expend not exceeding $500 for assistance in the preparation of its report.

DEXTER BRACKETT,
F. F. FORBES,
F. A. MCINNES,
Committee.

That is all that the committee has to say on the matter.

On motion of Mr. George A. Stacy, the report of the committee was accepted and its recommendations adopted.

The President subsequently appointed Messrs. Frank A. McInnes, Dexter Brackett, Frank A. Barbour, William R. Conard, and George A. King as members of the committee.

Mr. Clarence Goldsmith, assistant engineer, High Pressure Fire Service, Public Works Department, Boston, Mass., read a paper entitled " Some Water Supply Problems Encountered in the Semi-Arid Regions of the United States," and dealing with the

water supplies of the cities of Los Angeles, Cal.; Butte, Mont.; and Denver and Colorado Springs, Colo. The President and Mr. Richard A. Hale made certain suggestions and asked certain questions which were answered by Mr. Goldsmith.

The President announced that a letter had been sent out to various water departments with a view to obtaining opinions as to the proper depth to which water pipes should be laid in various localities. He said that in Worcester the pipes were laid to the depth of about 4½ ft. to the center of the pipe, and this year the frost had gone down 6 ft.

EXECUTIVE COMMITTEE.

BOSTON, MASS., March 13, 1912.

Meeting of the Executive Committee of the New England Water Works Association at the rooms of the Association, 715 Tremont Temple, at 11.30 A.M.

Present: President George W. Batchelder, and members Frank A. McInnes, Millard F. Hicks, Morris Knowles, Robert Spurr Weston, George A. Stacy, Lewis M. Bancroft, George A. King, and Willard Kent.

Three applications for membership were received and recommended for admission, namely:

For members: Philander Betts, chief engineer, Public Utility Commission, State of New Jersey, Newark, N. J.; Charles E. Perry, civil engineer, Canajoharie, N. Y.

For associate: Francis H. Coffin & Co., Scranton, Pa.

A communication from Mr. B. N. Simin, civil engineer, of Moscow, Russia, together with notes on and blueprint of fire hydrants, was received and the Secretary was instructed to express to Mr. Simin the appreciation and thanks of the Association for his interest in the matter. The several papers were referred to the Committee on Fire Hydrants.

The President announced the result of the vote of the members of the Executive Committee on place for holding the next Annual Convention to be as follows: viz., Washington, D. C., 5; Phila-

delphia, Pa., 3; New York, 3; and the individual expense of attending convention in the places named to be approximately as follows: Washington, $37.50; Philadelphia, $30, and New York, $30.

On motion of Mr. Bancroft, seconded by Mr. McInnes, it was voted that the next annual convention of the New England Water Works Association be held in the city of Washington, D. C.

Voted, on motion of Mr. Weston, that the date of the next annual convention be Wednesday, Thursday, and Friday of the third week in September.

Voted, on motion of Mr. Knowles, that Mr. King and Mr. Kent be a committee to investigate and report on the expediency of visiting the Cape Cod Canal on the occasion of the June Outing.

Adjourned.

WILLARD KENT, *Secretary*.

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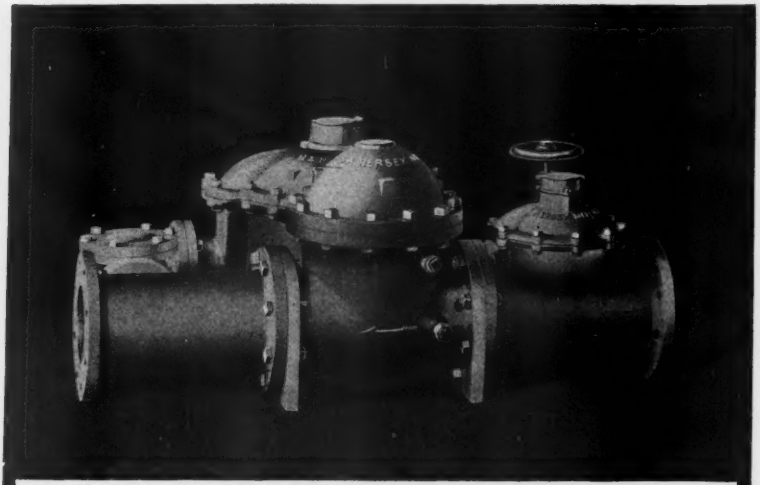

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Are the Requisites of the Perfect Water Meter and are the Principal Features of the

"LAMBERT."

Our unbreakable disk-piston, reinforced with an internal steel plate, can be found only in the **LAMBERT METER.**

The growing popularity of the water-meter system is attributed by many to the inherent excellence of the **"LAMBERT"** meter. Where **"LAMBERT"** meters are selected, success is assured.

THOMSON METER CO.

100-110 BRIDGE ST.
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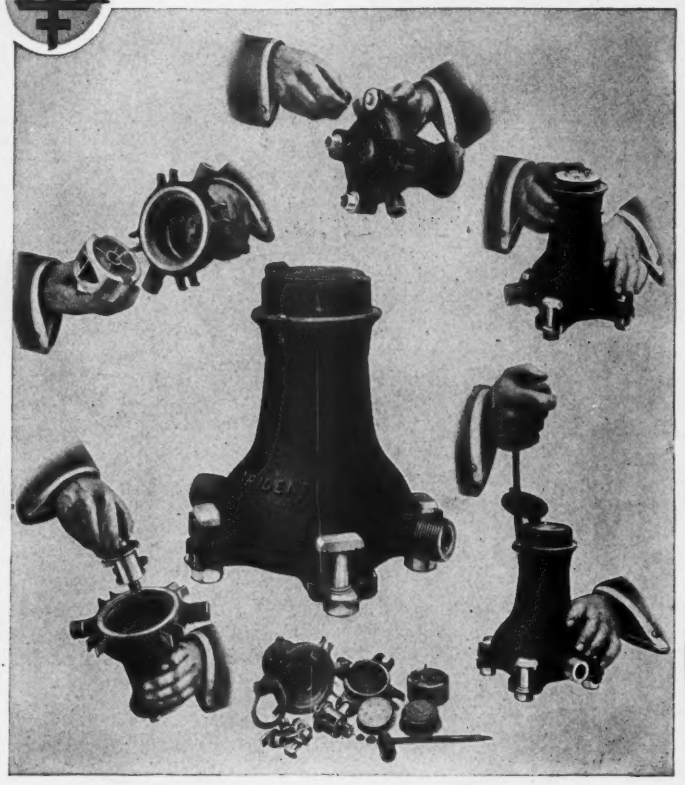
TRIDENT WATER METERS



Assembling Simplicity of Trident Construction

The above cut shows a Trident-Disk Meter dismantled and the extreme ease with which it can be assembled, by first putting in the gear train, then the disk-chamber, the frost bottom next, then the register and register box and the meter is complete. The Trident combination wrench is the only tool necessary to use.

NEPTUNE METER COMPANY

90 WEST STREET NEW YORK

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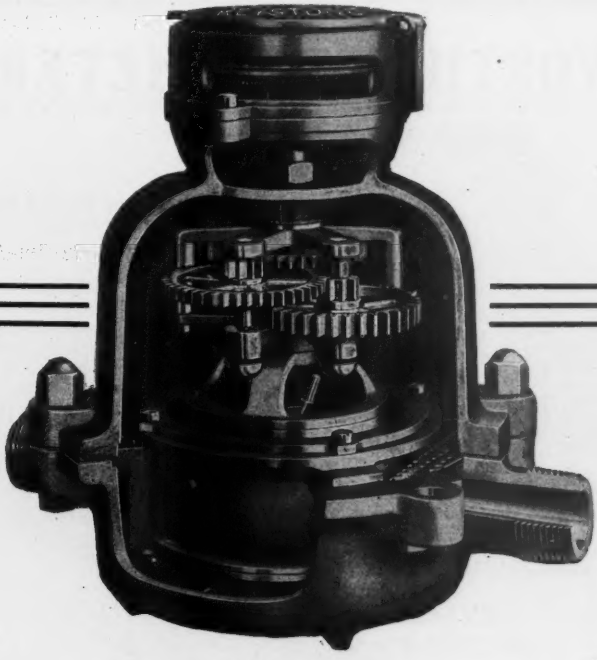
ATLANTA, LOS ANGELES, PORTLAND, SEATTLE



Keystone Water Meters

THE superiority of Keystone Water Meters has been established by their simplicity in construction and operation, the quality and durability of their materials, and their continued accuracy during prolonged service.

5000 cities and towns now use them with complete satisfaction to consumers and water companies.

Write us for Catalogue No. 108.

PITTSBURGH METER COMPANY

Also Manufacturers of Eureka Water Meters: Cast Iron and Tin Gas Meters: Positive and Proportional Gas Meters for any pressure: and Meter Provers.

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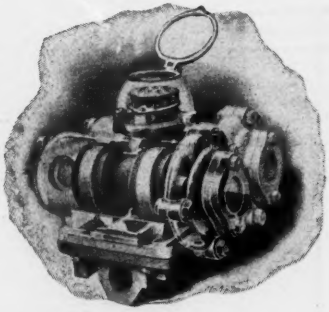
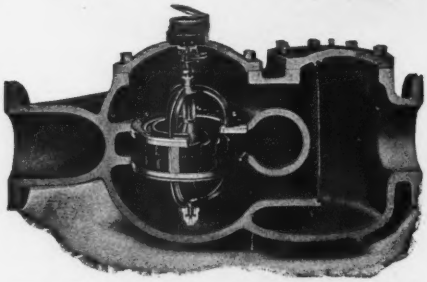
WORTHINGTON METERS

The Worthington Disc Meter combines minimum weight with reliability on constant service and accuracy of registration.

The Worthington Duplex Piston Meter is particularly adapted to large and heavy water works services.





The Worthington Turbine Meter
is designed primarily to handle large volumes of water with minimum loss of pressure.

Full descriptions of the different types of Worthington Meters, with tables of sizes and capacities, are given in Bulletin W184–54.

HENRY R. WORTHINGTON
WORKS: HARRISON, N. J. New York Office: 115 Broadway

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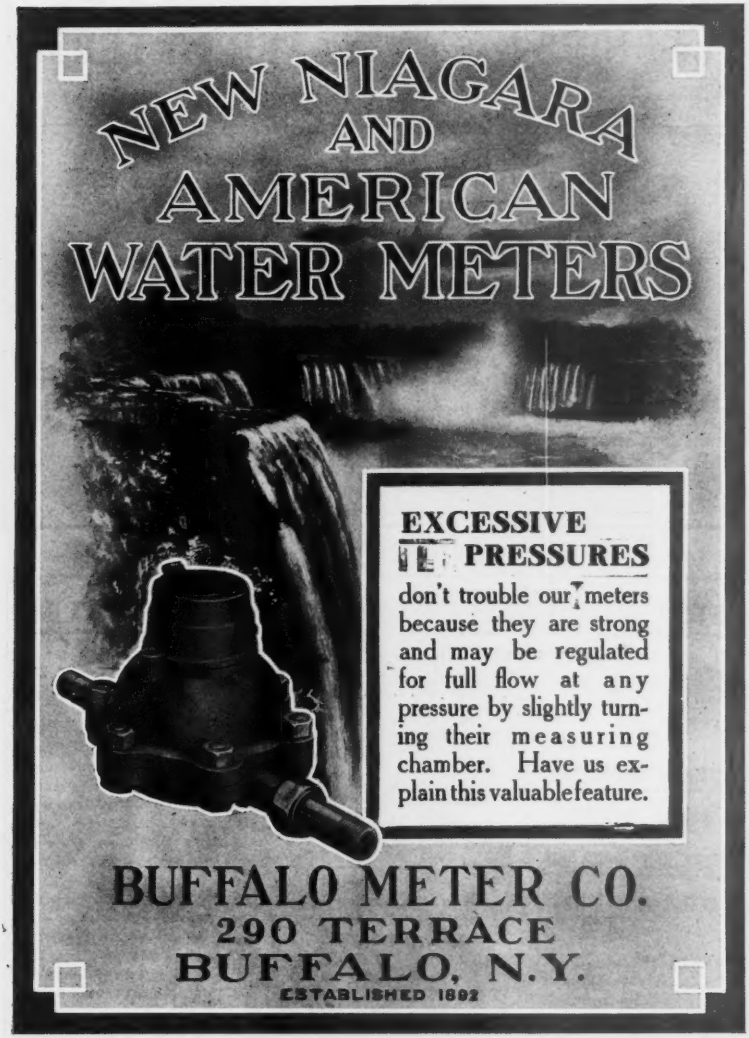
W159.8


NEW NIAGARA
AND
AMERICAN
WATER METERS
EXCESSIVE
PRESSURES
don't trouble our meters because they are strong and may be regulated for full flow at any pressure by slightly turning their measuring chamber. Have us explain this valuable feature.
BUFFALO METER CO.
290 TERRACE
BUFFALO, N.Y.
ESTABLISHED 1892

Distributers for New England

GEO. E. GILCHRIST CO.

106 HIGH STREET

BOSTON, MASS.

UNION ROTARY, COLUMBIA, DISC and NILO (Velocity) WATER METERS

Water Pressure Regulators
Waste Stops and Corporations

UNION WATER METER COMPANY
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STOP THE UNDERGROUND WASTE OF WATER!

It is now known that UNDERGROUND leakage may be enormous. The PITOMETER is the most efficient Waste Meter known. Adopted by New York City, Washington, D. C., Chicago, St. Louis, Indianapolis, Pittsburgh, Memphis, etc.

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MANUAL RECORDERS
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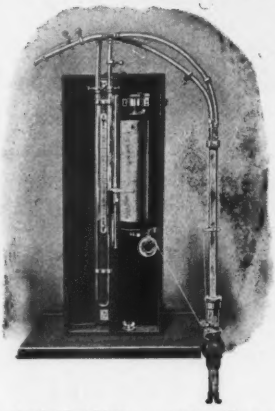
The City of Washington, D. C., has found and stopped underground leakage amounting to over 30,000,000 gallons daily with our Pitometer. A saving worth $5,000,000 to the city.



The Pitometer is portable and will accurately indicate or record the flow of water in a pipe of any size, under any pressure, without cutting the main. Only a one-inch tap is needed.

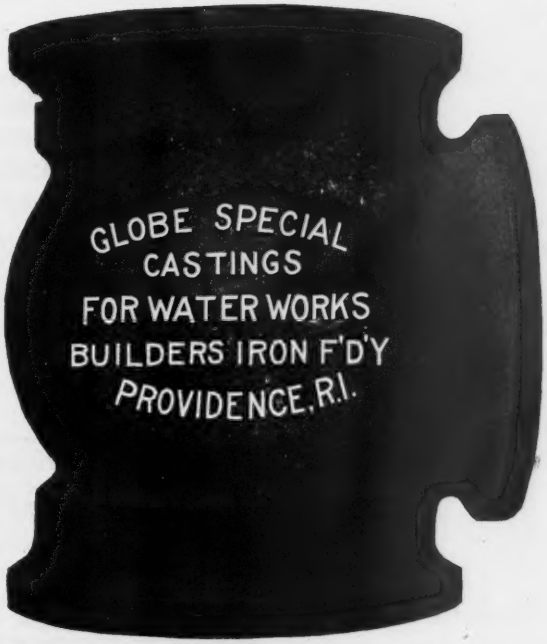
We make water waste surveys for cities, or we sell or rent our instruments and help you to organize a Pitometer department of your own.

Write for Information

THE PITOMETER COMPANY, 220 Broadway, New York

Venturi Meters

AND



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Established 1820 *Incorporated 1853*

THIS IS THE FAMOUS

BLACK SQUADRON

METALLIC

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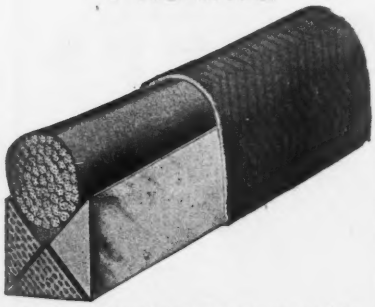

That is used exclusively in so many of the largest and most up-to-date water-works pumping stations throughout the world.

Send for free samples of high-pressure, low-pressure and semi-metallic. Also send for sample of Cancos Metal Polish.

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You Should Use "CLARK METER BOXES" "TEKSAGON" METER COUPLINGS AND OTHER WATER WORKS APPLIANCES OF OUR MANUFACTURE.

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For the lubrication of hydrants, gates, etc.

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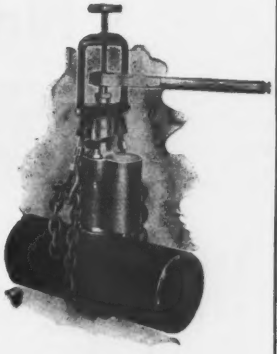
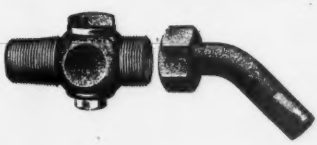


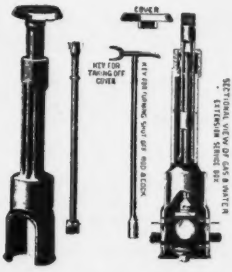
Do the best work, because they have

Few Working Parts
Compact
Simple in Construction
Light in Weight

We can prove these facts by sending a machine to you on thirty days' trial.

Long Main-End Corporation Cocks can be used





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High-Grade Water Works Brass Goods

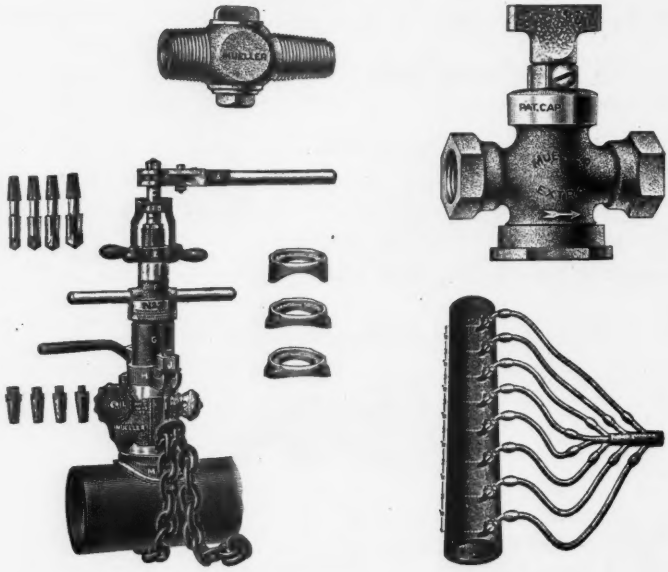
to suit every requirement

Experience of hundreds of water companies has proven that original "HAYS-ERIE" SERVICE BOXES give the best satisfaction

Ask for Samples and Prices

Hays Manufacturing Co. **Erie, Penna.**

Friends That Never Fail You



MUELLER UNCONDITIONALLY GUARANTEED WATER WORKS GOODS are friends that every user appreciates — they are friends that never fail you.

Their record is one of enduring and satisfactory service.

We would be pleased to quote you on tapping machines, corporation cocks (regular or lead flange), goose necks (wipe joint or lead flange), curb cocks, any pattern, branch connections, water meter testers, tools, or in fact anything in the water-works line.

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We make **Pressure Regulating Valves** for all purposes, steam or water.

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We can interest you if you use a condenser.

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THE ROSS VALVE MFG. CO.
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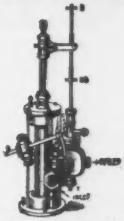
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MANUFACTURERS OF
"IMPROVED" WALKER FIRE HYDRANTS
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FOR WATER AND GAS
CHAS. MILLAR & SON CO., Selling Agents
Main Office, Utica, N. Y.
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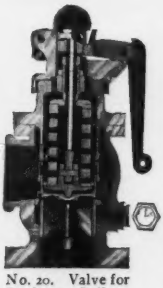
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They set the Pace
ASHTON POP VALVES
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No. 74. Recording and Indicating Gage.

Superior in Quality of material and workmanship, and with greatest efficiency and durability, they challenge comparison with any others on the market. Send a trial order subject to approval ONLY IF SATISFACTORY, and thereby prove the claims made for them. HIGH GRADE GOODS OUR EXCLUSIVE SPECIALTY.

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R. D. WOOD & CO.

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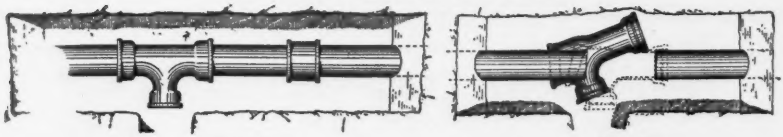
Engineers, Iron Founders and Machinists

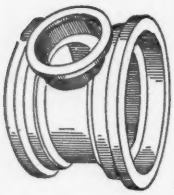
CENTRIFUGAL PUMPS
PUMPING ENGINES

Cast Iron Pipe

CUTTING-IN TEES



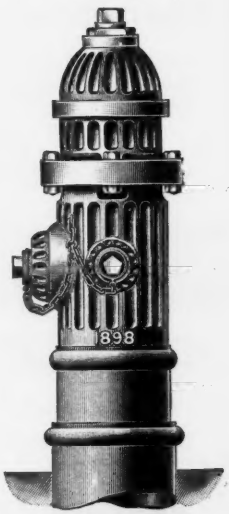
Old Way *Our Way*



Connections economically and easily made with one fitting. Saves sleeve, cuts, lead and unnecessary work and material.

"Reduced Specials"

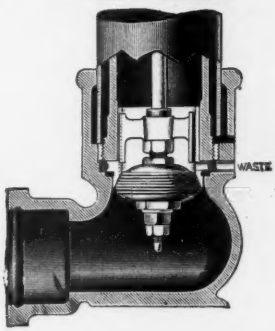
Cost of fittings reduced from 25% to 50%. Full strength. Deep bells. Convenient to handle. Sold by the piece.



Mathews Fire Hydrants

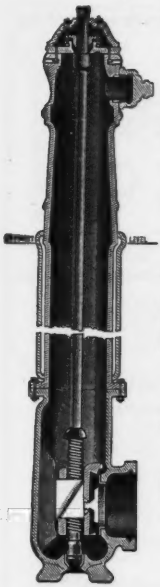
A half century of use has established their reputation as being the most economical, durable and simple hydrant.

Number in use exceeds total of all other makes combined.



Gate Valves

R. D. WOOD & CO. STANDARD
DOUBLE DISK
ANTI-FRICTION
EXTRA WEIGHT, FINISH
AND MATERIAL



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VALVES AND FIRE HYDRANTS

This hydrant is anti-freezing, because when the drainage is good no water is left in it to freeze.
The drip is directly in the bottom of the hydrant and drains perfectly. It is protected by its valve, which never leaves its socket and cannot be clogged.

DOUBLE AND SINGLE GATE VALVES,
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YARD, WASH, AND FLUSH HYDRANTS.

SEND FOR CIRCULARS.

OFFICE AND WORKS: FOOT OF ADAMS STREET, TROY, N. Y.

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STANDARD CAST IRON PIPE & FOUNDRY CO.

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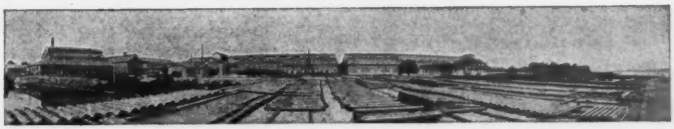
CAST IRON PIPE AND SPECIAL CASTINGS

GENERAL FOUNDRY AND MACHINE WORK



PLANT LOCATED ON DELAWARE RIVER

Most Modern and Best Equipped Cast Iron Pipe Plant in America

Shipments made Either by Water or Rail

THE CHAPMAN
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The "COREY" FIRE HYDRANT

MODERN
SUCCESSFUL
SIMPLE
DURABLE

SUPERIOR

RENSSELAER VALVES

ALL SIZES ALL PRESSURES

WATER, STEAM, GAS, OIL, ETC.

ELECTRICALLY OPERATED VALVES
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Established 1856

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Cast Iron Water and Gas **PIPE** From 3 to 60 inches in diameter.

ALSO

ALL SIZES OF FLANGED PIPE

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THE NEW YORK CONTINENTAL JEWELL FILTRATION CO.

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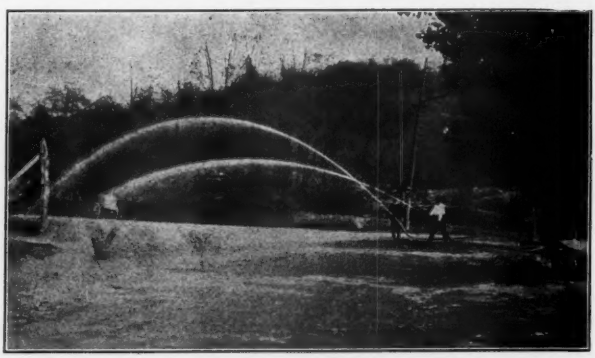

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ENOUGH WATER?

If not, it is probably because of lack of carrying capacity of your mains. Consult us.

Illustrated booklet upon request

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FOR WATER AND GAS

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Special Castings for Water and Gas.
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ALL REGULAR SIZES, 3 INCHES TO 84 INCHES

FOR WATER, GAS, SEWERS, DRAINS, ETC.

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Manufacturers of

Tapping Machines, Fire Hydrants, Water Gates,
Economic Lead Furnaces,
Corporation and Curb Cocks, Brass and Aluminum Castings.
Also General Supplies for Water and Gas Works.

Write for Catalogue.

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WATER & GAS PIPES
FLANGE PIPE

Special Castings, Fire Hydrants, Valves
General Foundry and Machine Work
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HIGHEST AWARD, GOLD MEDAL,
ST. LOUIS EXPOSITION, 1904

Over 100 Water Departments
use
LEAD-LINED IRON and TIN-LINED PIPES
for their service connections

MANUFACTURED BY

Lead Lined Iron Pipe Company

Wakefield ═══ Mass.

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Corner Congress and Franklin Streets

162 Congress St. **BOSTON** **180 & 182 Franklin St.**

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Patent Tin-lined Pipe

Pure Block Tin Pipe

PIG LEAD

(Best Brands for Joint Work always in Stock)

Pig Tin, Wire Solder, Pumps, etc.

ALSO

"Forest River" and "Star" Brands

PURE WHITE LEAD

Perolin

from Germany

Came over without paying duty, too!

But it had a big duty to perform, so, to avoid the Import Tax, it came in the form of a formula — *D. R. Dampf-Kessel-Mischung* is what the Germans call it. Translated into boiler talk this means

'Raus Mit 'Em—Scale

And that it does "'Raus Mit 'Em" is proved by the fact that in Germany and Europe eleven large factories are taxed to their full capacity in supplying the enormous demand.

Perolin German Boiler Compound

was first introduced in this country two years ago. During this short period it certainly has lived up to its home reputation, for the names of over 4,000 customers are on our books today, and they use *Perolin* exclusively.

And in each instance *Perolin* went in "on trial," without requesting a "Jug of Feed Water" or a "Sample of Scale for Chemical Analysis," for the source of your water supply and the character of scale it deposits are merely incidental.

Perolin will increase the efficiency of your plant and lessen the labor of the fireman, by solving the scale problem at a lower cost than any other known method.

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EAGLE OIL & SUPPLY CO.
I will cheerfully show any skeptic, as I was at first, that Perolin does the work — I shall continue to use it and find it cheaper than sal soda.
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McLane Mfg. Co.
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EAGLE OIL & SUPPLY CO.
Gentlemen:
We have been using your boiler compound for three months and find it will remove scale, and we do not observe any injury to boiler.
McLane Mfg. Co.

Write for a copy of "It Doesn't Affect the Water," which tells all about our proposition and the guarantee that we insist upon making.

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